US 20120077062A1

(19) United States
(12) Patent Application Publication
Fuhr et al.
(10) Pub. No.: US 2012/0077062 A1
(43) Pub. Date: Mar. 29, 2012

(54) **VENT FOR ELECTROCHEMICAL CELL**

(75) Inventors: **Jason D. Fuhr**, Sussex, WI (US); **Wataru Tsutsui**, West Lafayette, IN (US); **Gary P. Houchin-Miller**, Milwakee, WI (US); **Christopher M. Bonin**, South Milwaukee, WI (US)

(73) Assignee: **Johnson Controls - SAFT Advanced Power Solutions LLC**

(21) Appl. No.: **13/270,147**

(22) Filed: **Oct. 10, 2011**

Related U.S. Application Data

(63) Continuation of application No. PCT/US2010/031065, filed on Apr. 14, 2010.

(60) Provisional application No. 61/169,657, filed on Apr. 15, 2009, provisional application No. 61/172,148, filed on Apr. 23, 2009.

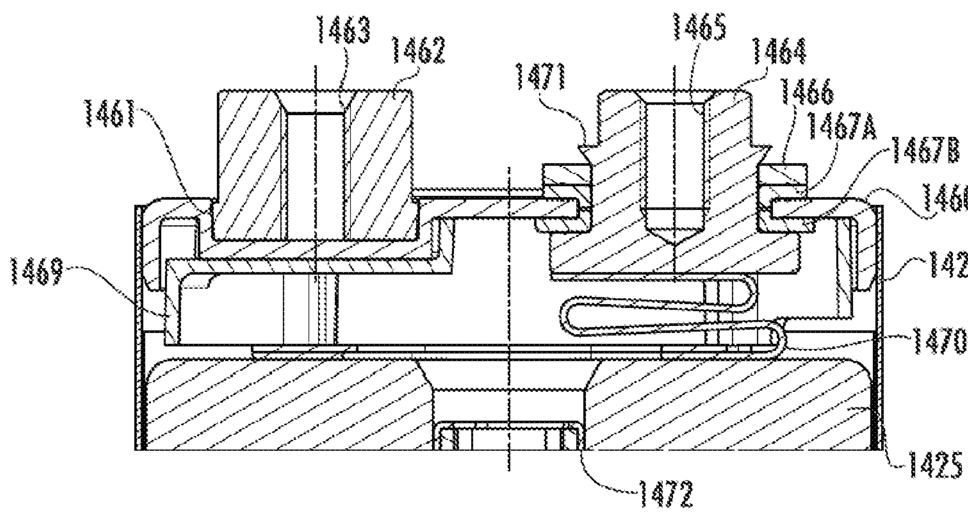
Publication Classification

(51) **Int. Cl.**
H01M 2/12 (2006.01)

(52) **U.S. Cl.** **429/56**

(57) **ABSTRACT**

An electrochemical cell includes a housing having a first end and a vent located at the first end that is configured to deploy from the housing to allow the expulsion of gases from within the cell. The electrochemical cell also includes at least one projection extending outward from the first end adjacent the vent. The at least one projection is configured to prevent accidental deployment of the vent.



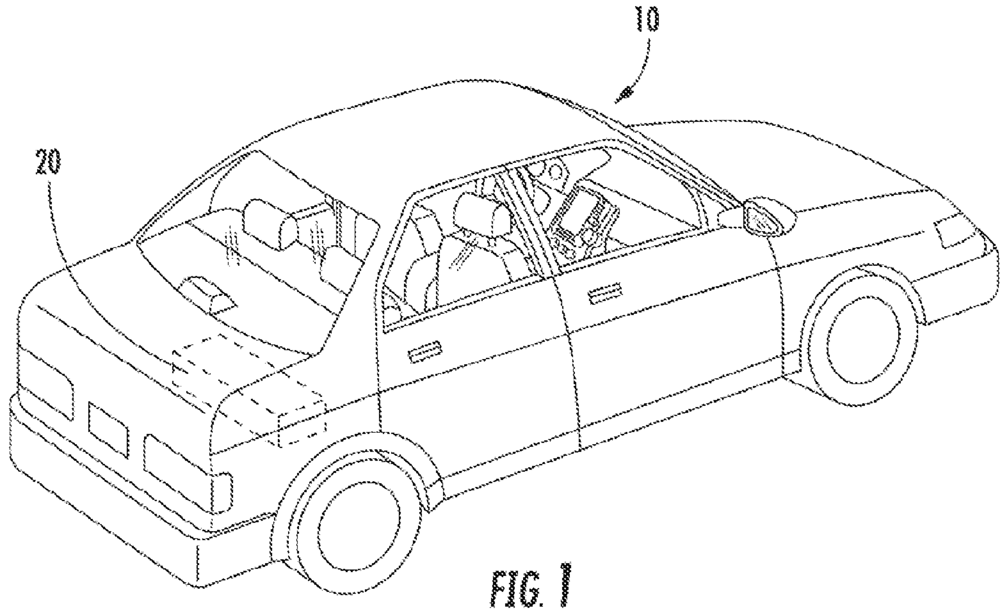


FIG. 1

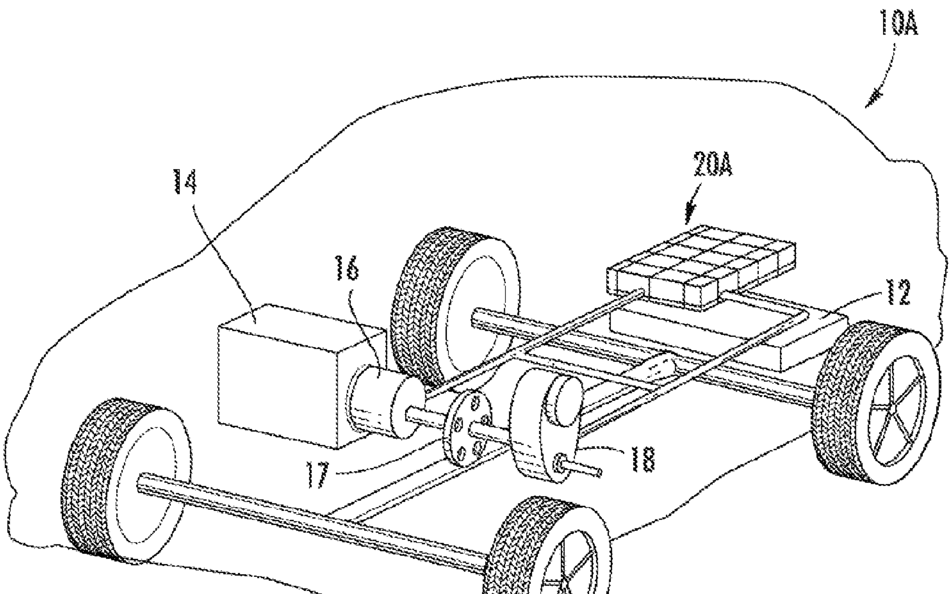


FIG. 2

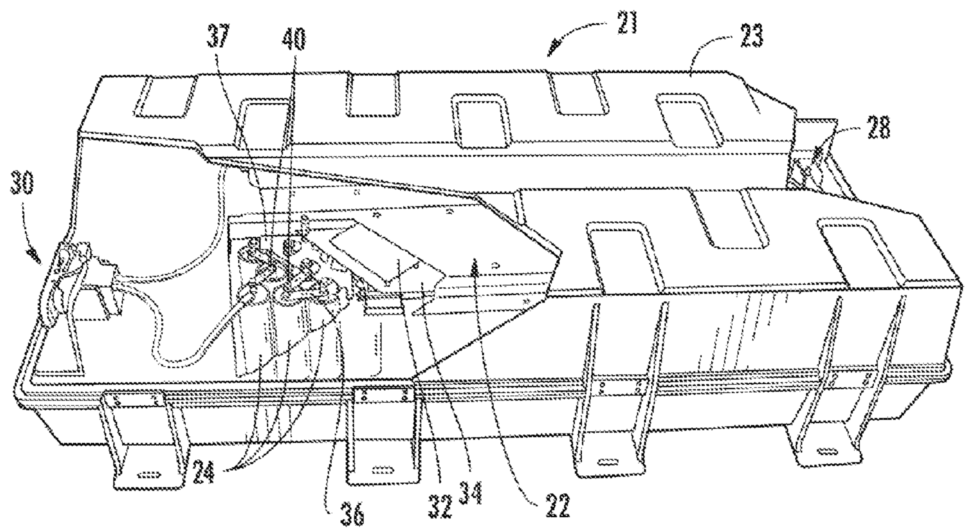


FIG. 3

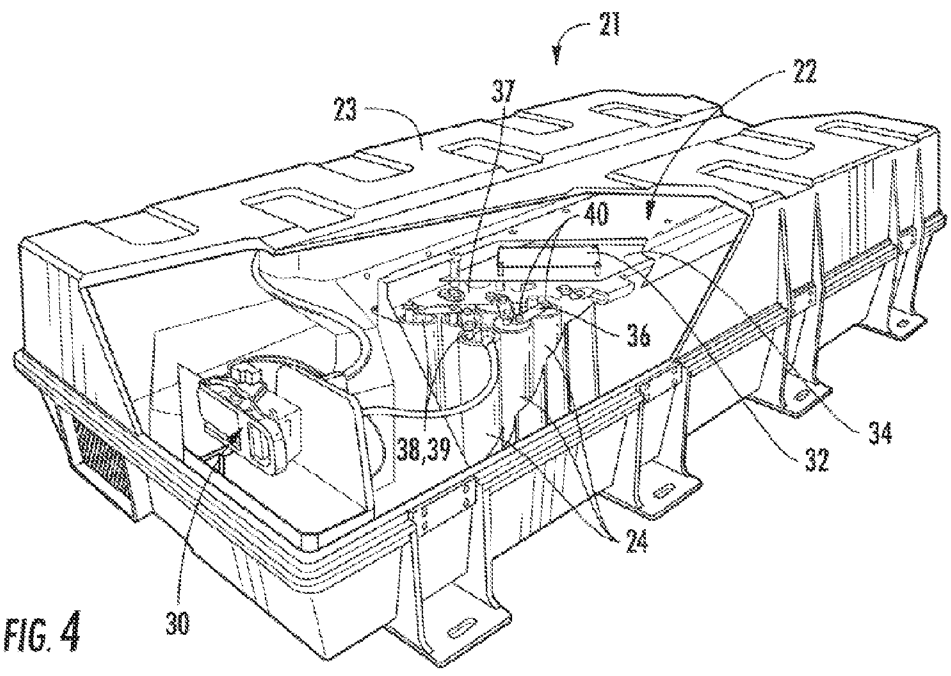


FIG. 4

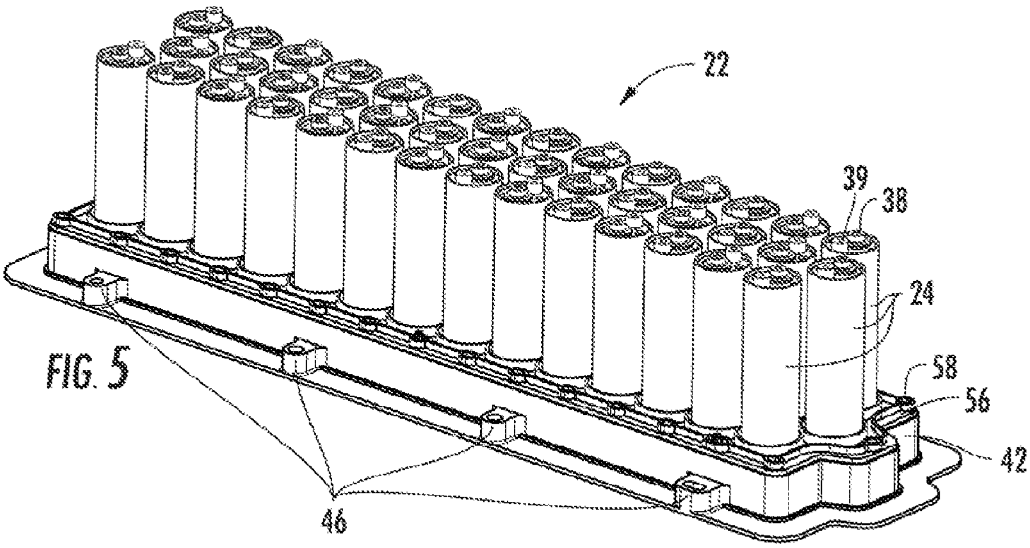


FIG. 5

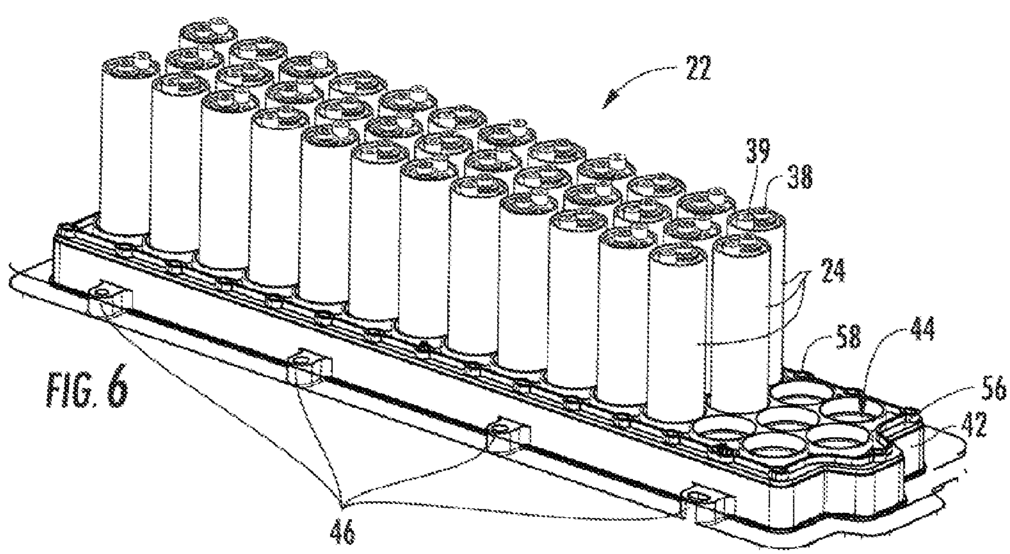


FIG. 6

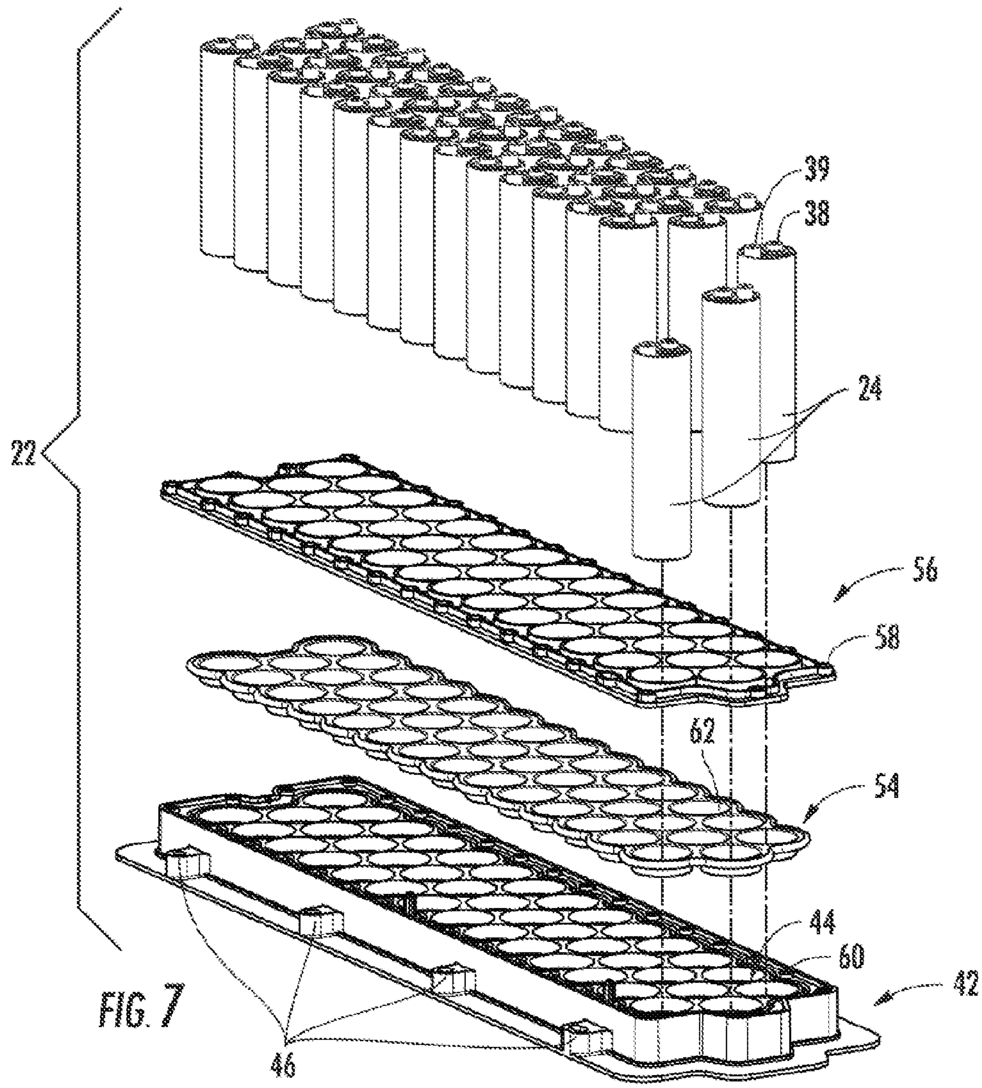


FIG. 7

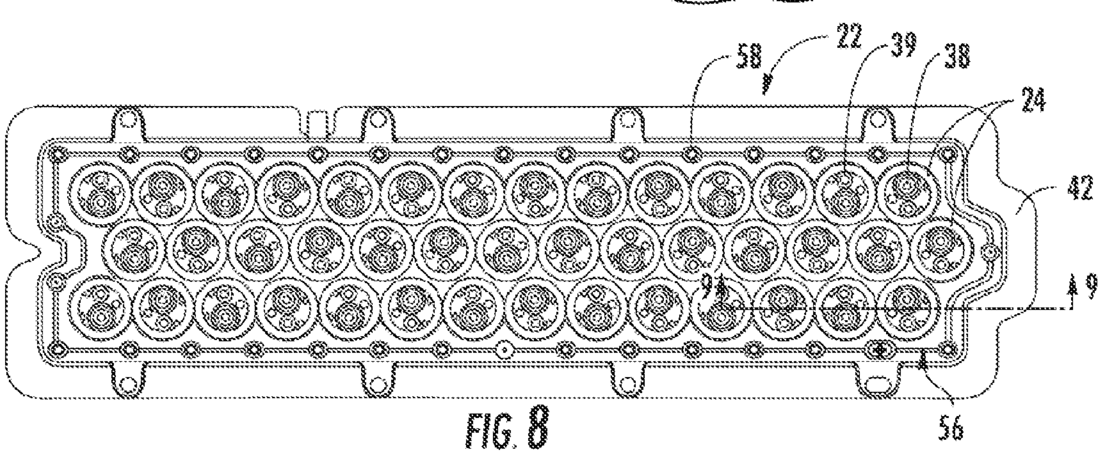
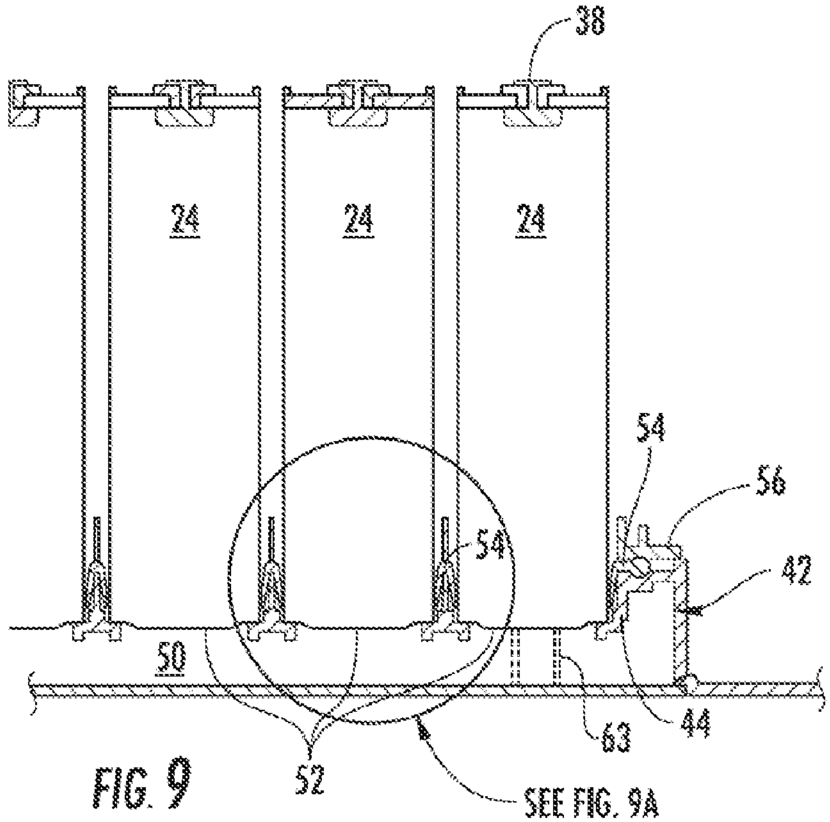


FIG. 8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SEE FIG. 9A

FIG. 9

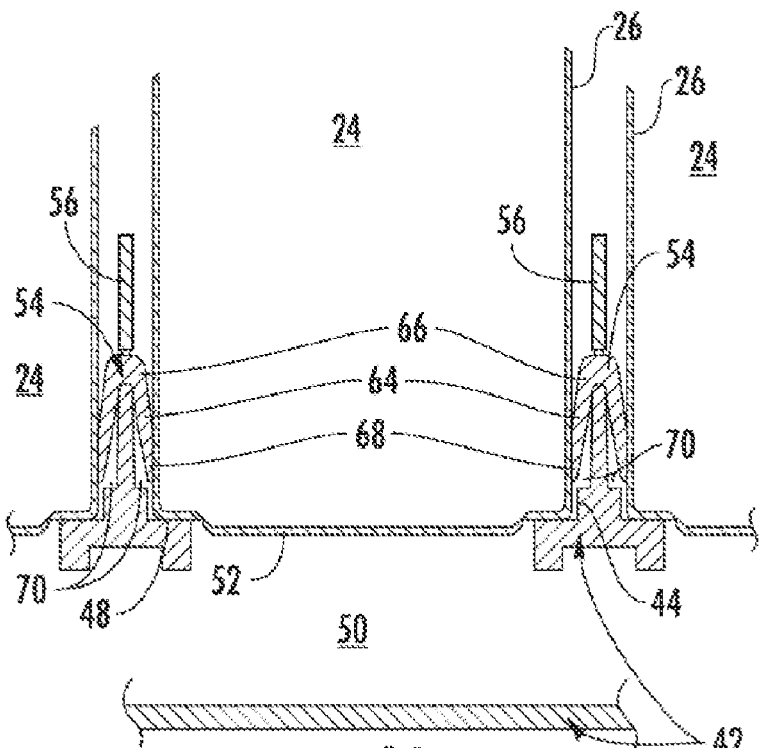
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FIG. 9A

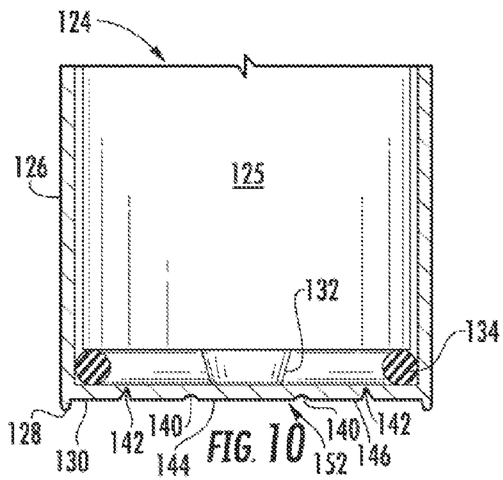

FIG. 10

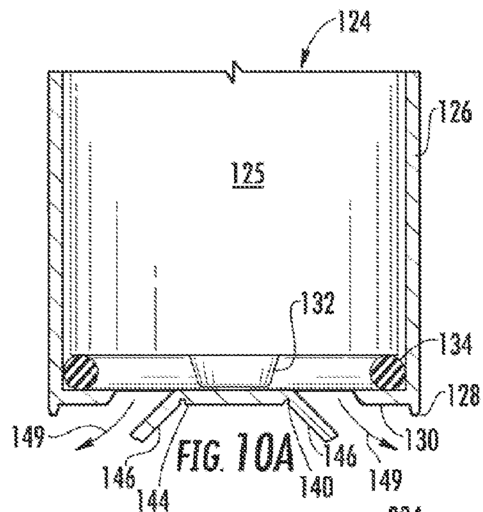

FIG. 10A

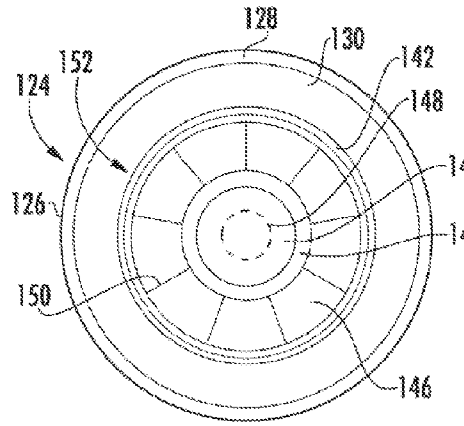

FIG. 10B

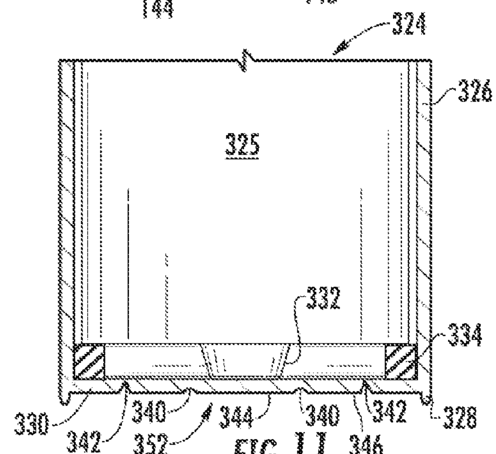

FIG. 11

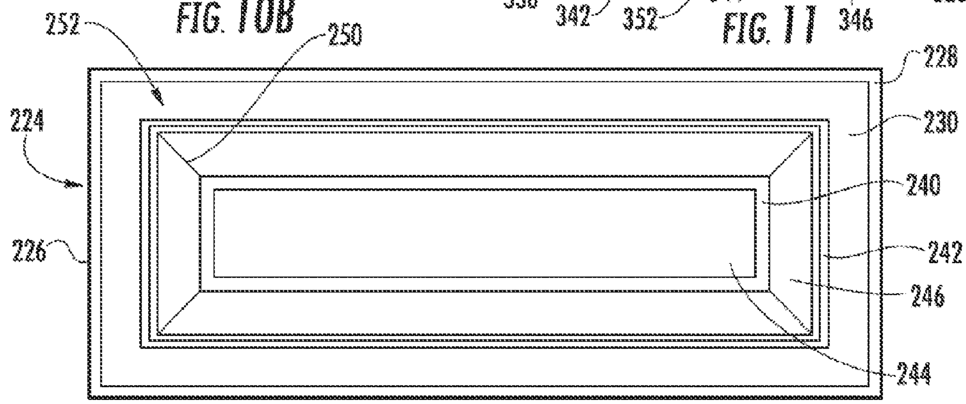

FIG. 10C

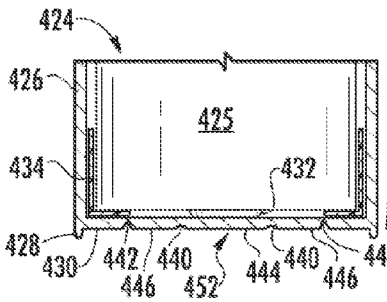

FIG. 12A

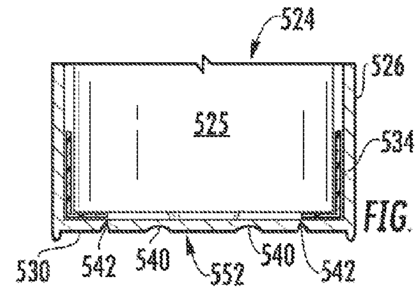

FIG. 12B

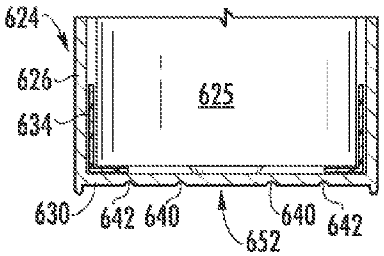

FIG. 12C

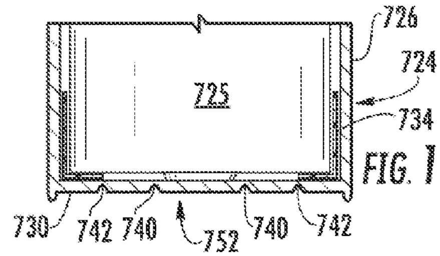

FIG. 12D

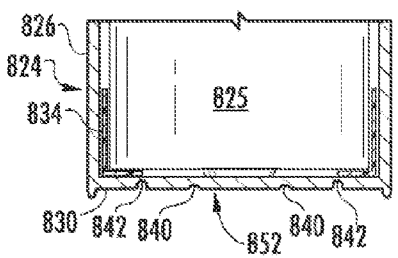

FIG. 12E

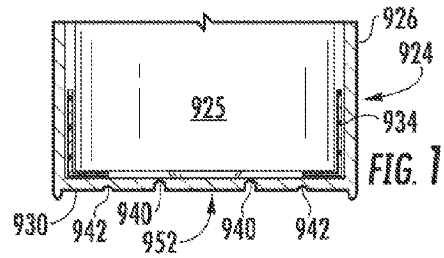

FIG. 12F

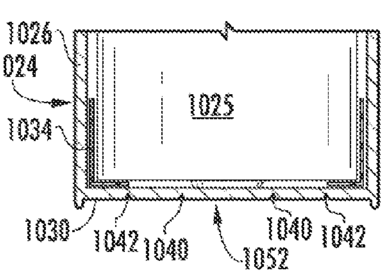

FIG. 12G

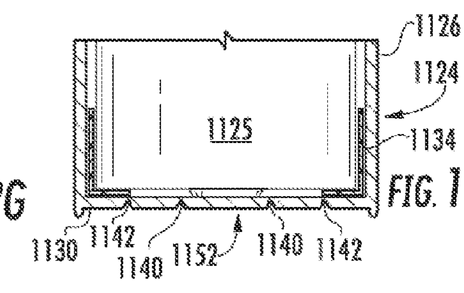

FIG. 12H

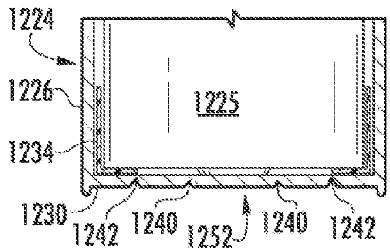

FIG. 12I

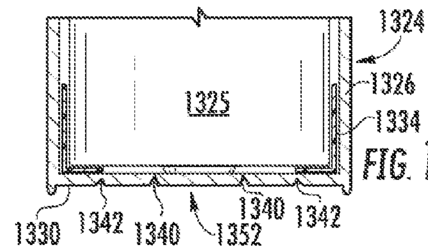

FIG. 12J

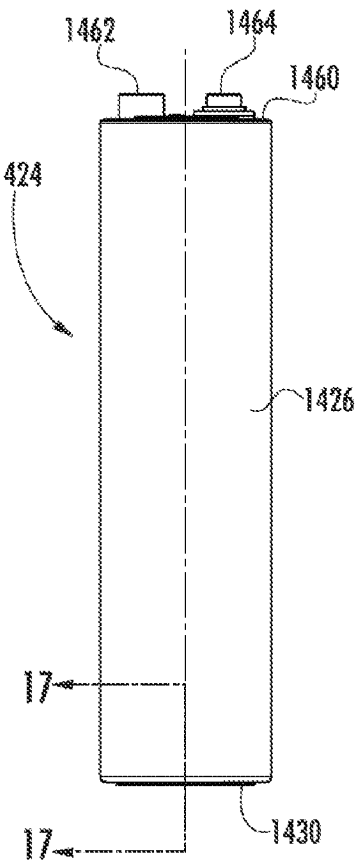

FIG. 13

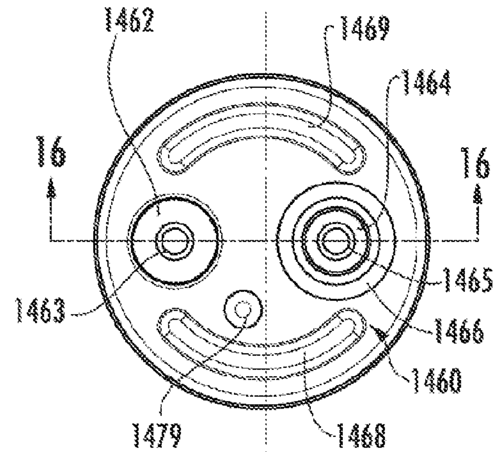

FIG. 14

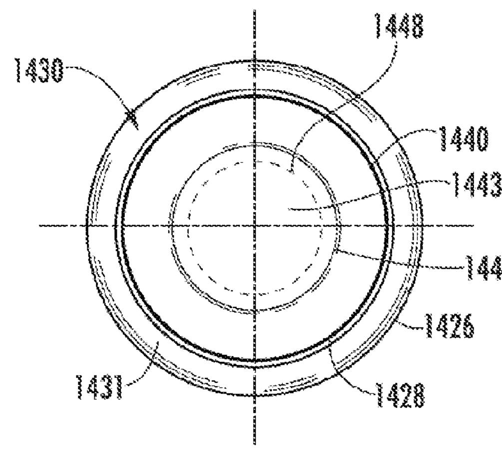

FIG. 15

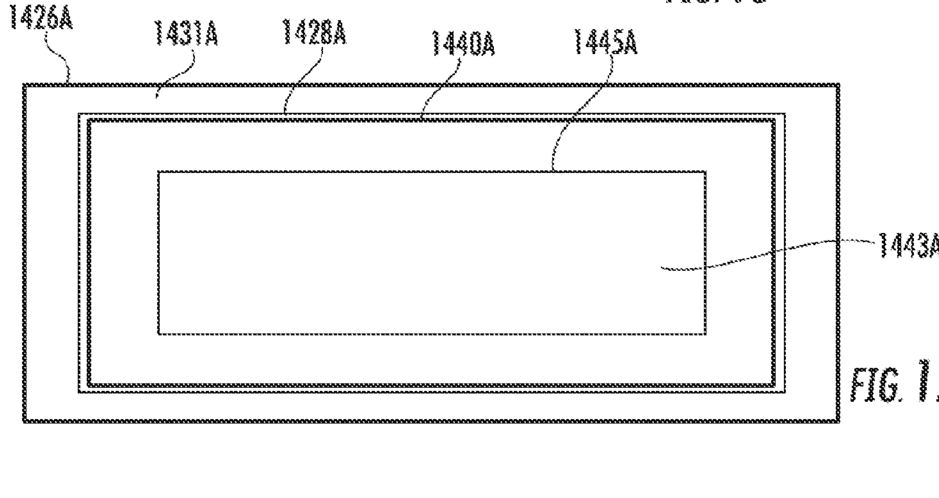

FIG. 15A

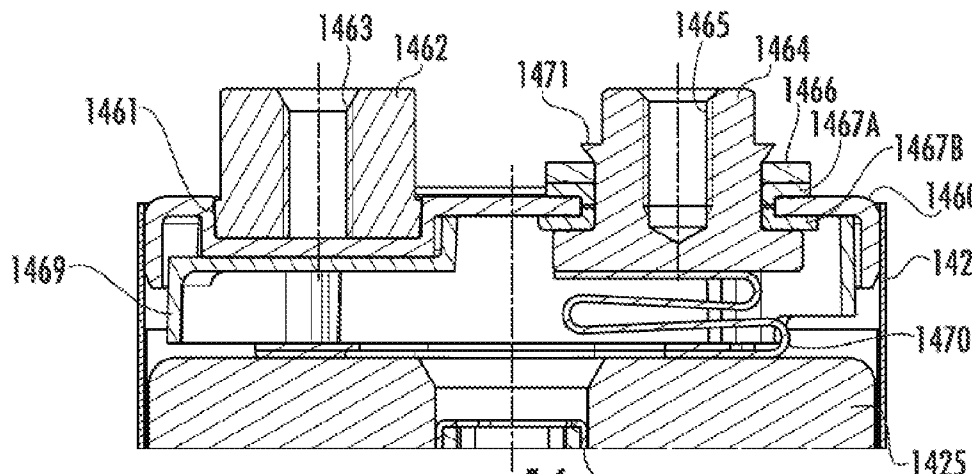

FIG. 16

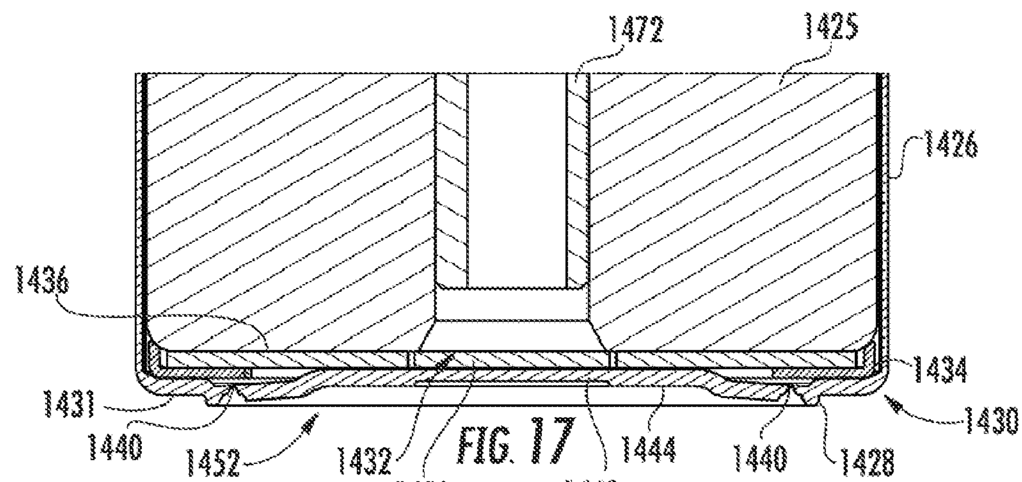

FIG. 17

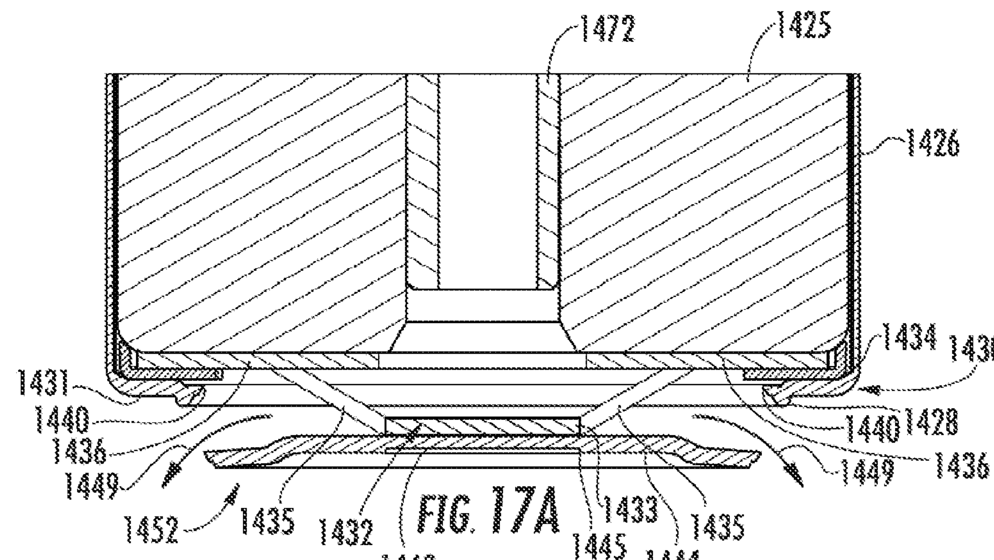

FIG. 17A

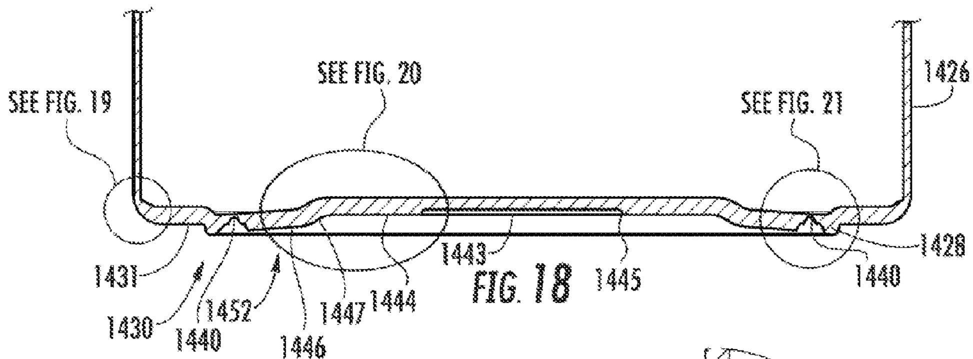

FIG. 18

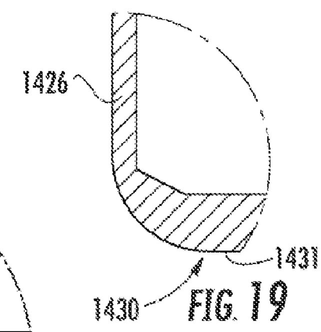

FIG. 19

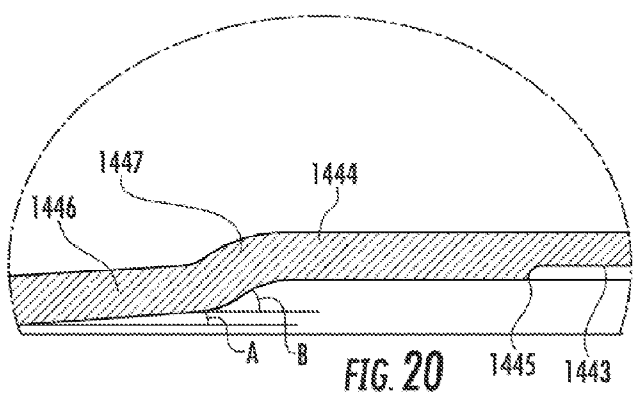

FIG. 20

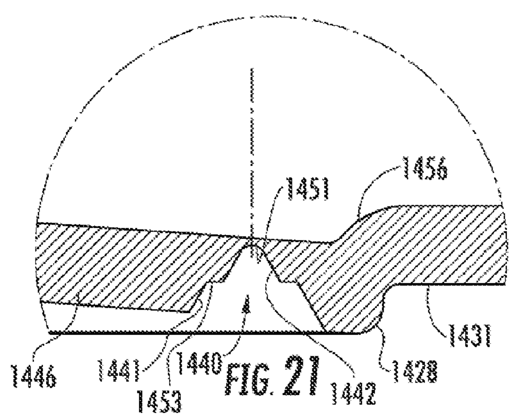

FIG. 21

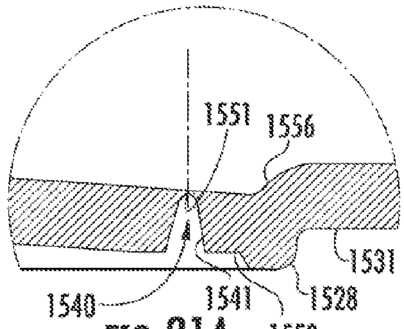

FIG. 21A

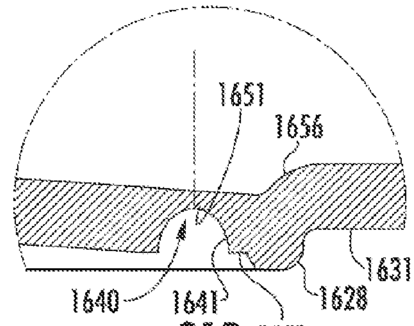

FIG. 21B

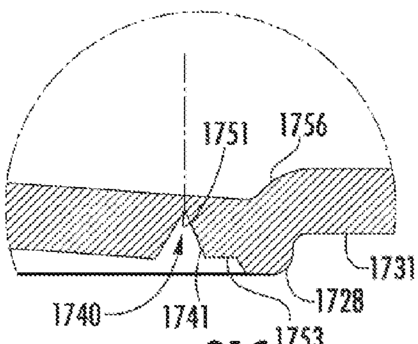

FIG. 21C

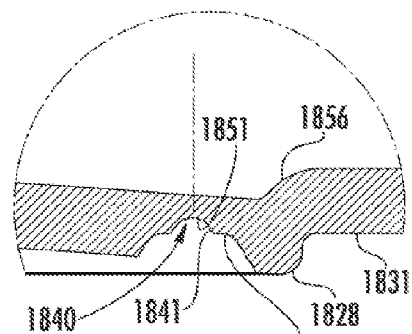

FIG. 21D

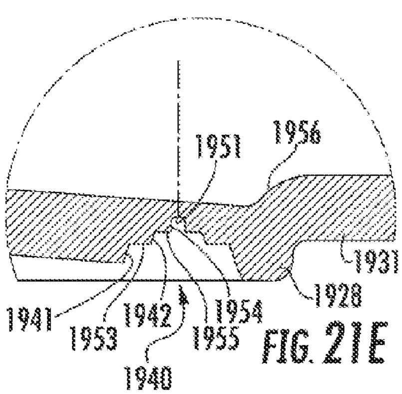

FIG. 21E

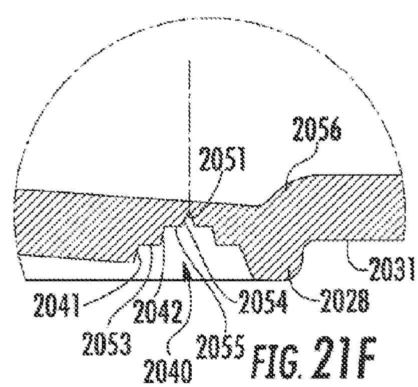

FIG. 21F

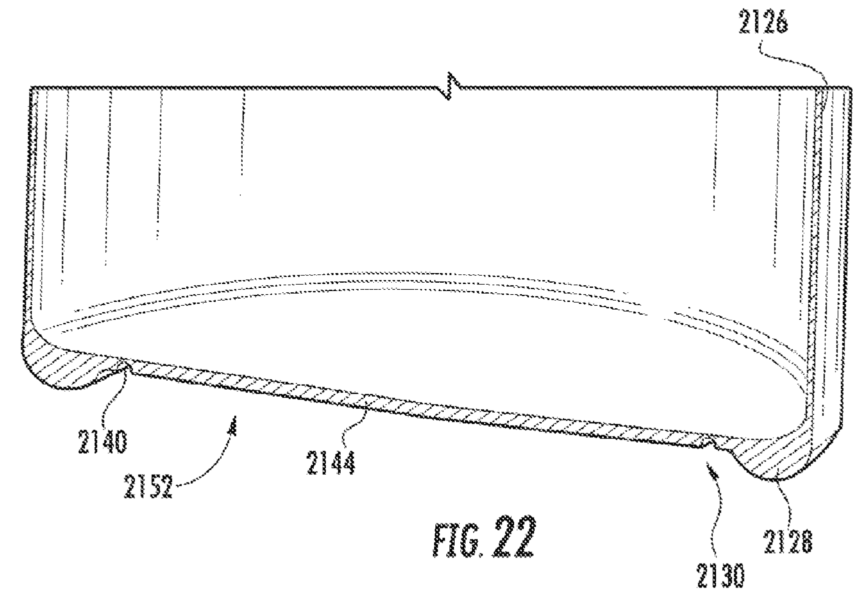
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FIG. 22

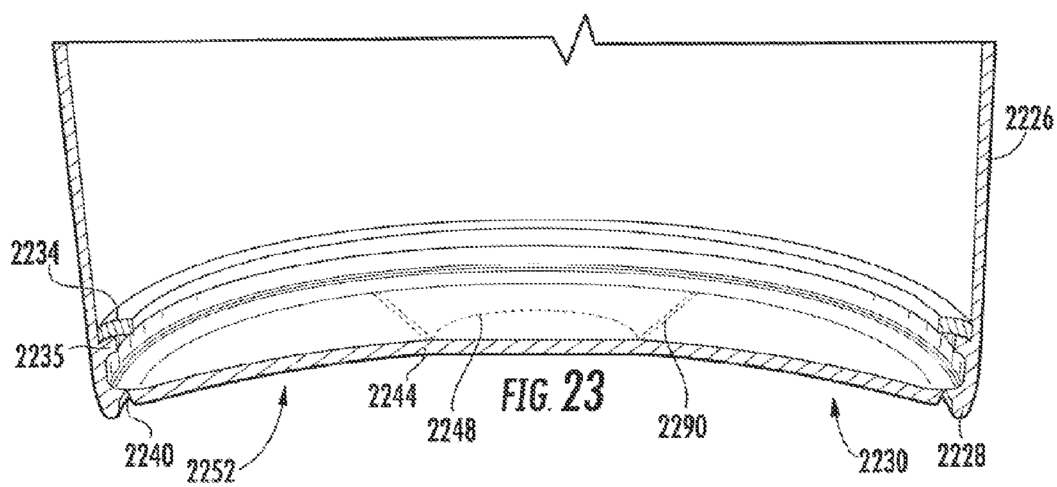
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FIG. 23

VENT FOR ELECTROCHEMICAL CELL

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application is a continuation of International Patent Application No. PCT/US2010/031065, filed Apr. 14, 2010, which claims the benefit of and priority to U.S. Provisional Patent Application No. 61/169,657, filed Apr. 15, 2009 and U.S. Provisional Patent Application No. 61/172,148, filed Apr. 23, 2009. The entire disclosures of International Patent Application No. PCT/US2010/031065, U.S. Provisional Patent Application No. 61/169,657, and U.S. Provisional Patent Application No. 61/172,148 are incorporated herein by reference.

BACKGROUND

[0002] The present application relates generally to the field of batteries and battery systems. More specifically, the present application relates to batteries and battery systems that may be used in vehicle applications to provide at least a portion of the motive power for the vehicle.

[0003] Vehicles using electric power for all or a portion of their motive power (e.g., electric vehicles (EVs), hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and the like, collectively referred to as "electric vehicles") may provide a number of advantages as compared to more traditional gas-powered vehicles using internal combustion engines. For example, electric vehicles may produce fewer undesirable emission products and may exhibit greater fuel efficiency as compared to vehicles using internal combustion engines (and, in some cases, such vehicles may eliminate the use of gasoline entirely, as is the case of certain types of PHEVs).

[0004] As electric vehicle technology continues to evolve, there is a need to provide improved power sources (e.g., battery systems or modules) for such vehicles. For example, it is desirable to increase the distance that such vehicles may travel without the need to recharge the batteries. It is also desirable to improve the performance of such batteries and to reduce the cost associated with the battery systems.

[0005] One area of improvement that continues to develop is in the area of battery chemistry. Early electric vehicle systems employed nickel-metal-hydride (NiMH) batteries as a propulsion source. Over time, different additives and modifications have improved the performance, reliability, and utility of NiMH batteries.

[0006] More recently, manufacturers have begun to develop lithium-ion batteries that may be used in electric vehicles. There are several advantages associated with using lithium-ion batteries for vehicle applications. For example, lithium-ion batteries have a higher charge density and specific power than NiMH batteries. Stated another way, lithium-ion batteries may be smaller than NiMH batteries while storing the same amount of charge, which may allow for weight and space savings in the electric vehicle (or, alternatively, this feature may allow manufacturers to provide a greater amount of power for the vehicle without increasing the weight of the vehicle or the space taken up by the battery system).

[0007] It is generally known that lithium-ion batteries perform differently than NiMH batteries and may present design and engineering challenges that differ from those presented with NiMH battery technology. For example, lithium-ion batteries may be more susceptible to variations in battery temperature than comparable NiMH batteries, and thus systems may be used to regulate the temperatures of the lithium-ion batteries during vehicle operation. The manufacture of lithium-ion batteries also presents challenges unique to this battery chemistry, and new methods and systems are being developed to address such challenges.

[0008] It would be desirable to provide an improved battery module and/or system for use in electric vehicles that addresses one or more challenges associated with NiMH and/or lithium-ion battery systems used in such vehicles. It also would be desirable to provide a battery module and/or system that includes any one or more of the advantageous features that will be apparent from a review of the present disclosure.

SUMMARY

[0009] According to an exemplary embodiment, an electrochemical cell includes a housing having a first end and a vent located at the first end that is configured to deploy from the housing to allow the expulsion of gases from within the cell. The electrochemical cell also includes at least one projection extending outward from the first end adjacent the vent. The at least one projection is configured to prevent accidental deployment of the vent.

[0010] According to an exemplary embodiment, an electrochemical cell includes a housing and a vent located at a first end of the housing. The vent is configured to separate from the first end of the housing to allow gases from within the cell to exit the cell. The cell also includes at least one projection extending outward from the first end of the housing and partially surrounding at least a portion of the vent. The at least one projection is configured to prevent accidental deployment of the vent.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a perspective view of a vehicle including a battery system according to an exemplary embodiment.

[0012] FIG. **2** is a cutaway schematic view of a vehicle including a battery system according to an exemplary embodiment.

[0013] FIGS. **3-4** are partial cutaway views of a battery system according to an exemplary embodiment.

[0014] FIGS. **5-6** are isometric views of a portion of a battery module for use in a battery system according to an exemplary embodiment.

[0015] FIG. **7** is a partial exploded view of the battery module of FIG. **5**.

[0016] FIG. **8** is a top view of the battery module of FIG. **5**.

[0017] FIG. **9** is a cross-sectional view of a portion of the battery module of FIG. **8** taken along line **9-9** of FIG. **8**.

[0018] FIG. **9**A is a detail view of a portion of the battery module of FIG. **9**.

[0019] FIG. **10** is a cross-sectional view of a portion of an electrochemical cell having a vent according to an exemplary embodiment.

[0020] FIG. **10**A is a detail view of the portion of the electrochemical cell of FIG. **10** showing the vent in a deployed state according to an exemplary embodiment.

[0021] FIG. **10**B is a bottom view of the electrochemical cell of FIG. **10** according to an exemplary embodiment.

[0022] FIG. **10**C is a bottom view of an electrochemical cell having features similar to the electrochemical cell of FIGS. **10-10**B according to another exemplary embodiment.

[0023] FIG. **11** is a cross-sectional view of an electrochemical cell having a vent according to another exemplary embodiment.

[0024] FIGS. **12**A-**12**J are cross-sectional views of an electrochemical cell having a vent according to various other exemplary embodiments.

[0025] FIG. **13** is a side view of an electrochemical cell according to another exemplary embodiment.

[0026] FIG. **14** is a top view of the electrochemical cell of FIG. **13** according to an exemplary embodiment.

[0027] FIG. **15** is a bottom view of the electrochemical cell of FIG. **13** according to an exemplary embodiment.

[0028] FIG. **15**A is a bottom view of an electrochemical cell having features similar to the electrochemical cell of FIGS. **13-15** according to another exemplary embodiment.

[0029] FIG. **16** is a cross-sectional view of a portion of the electrochemical cell of FIG. **13** taken along line **16-16** of FIG. **14** according to an exemplary embodiment.

[0030] FIG. **17** is a cross-sectional view of a portion of the electrochemical cell of FIG. **13** taken along line **17-17** of FIG. **13** according to an exemplary embodiment.

[0031] FIG. **17**A is a cross-sectional view of the portion of the electrochemical cell of FIG. **17** showing a vent in a deployed state according to an exemplary embodiment.

[0032] FIG. **18** is a detail view of a portion of a housing of the electrochemical cell of FIG. **17** showing a vent according to an exemplary embodiment.

[0033] FIG. **19** is a detail view of a portion of the housing of FIG. **18** according to an exemplary embodiment.

[0034] FIG. **20** is a detail view of a portion of the vent of FIG. **18** according to an exemplary embodiment.

[0035] FIGS. **21-21**F are detail views of a portion of a vent similar to that shown in FIG. **18** according to various exemplary embodiments.

[0036] FIG. **22** is a cross-sectional view of a portion of a housing having a vent for an electrochemical cell according to another exemplary embodiment.

[0037] FIG. **23** is a cross-sectional view of a portion of a housing having a vent for an electrochemical cell according to another exemplary embodiment.

DETAILED DESCRIPTION

[0038] FIG. **1** is a perspective view of a vehicle **10** in the form of an automobile (e.g., a car) having a battery system **20** for providing all or a portion of the motive power for the vehicle **10**. Such a vehicle **10** can be an electric vehicle (EV), a hybrid electric vehicle (HEV), a plug-in hybrid electric vehicle (PHEV), or other type of vehicle using electric power for propulsion (collectively referred to as "electric vehicles").

[0039] Although the vehicle **10** is illustrated as a car in FIG. **1**, the type of vehicle may differ according to other exemplary embodiments, all of which are intended to fall within the scope of the present disclosure. For example, the vehicle **10** may be a truck, bus, industrial vehicle, motorcycle, recreational vehicle, boat, or any other type of vehicle that may benefit from the use of electric power for all or a portion of its propulsion power.

[0040] Although the battery system **20** is illustrated in FIG. **1** as being positioned in the trunk or rear of the vehicle, according to other exemplary embodiments, the location of the battery system **20** may differ. For example, the position of the battery system **20** may be selected based on the available space within a vehicle, the desired weight balance of the vehicle, the location of other components used with the battery system **20** (e.g., battery management systems, vents, or cooling devices, etc.), and a variety of other considerations.

[0041] FIG. **2** illustrates a cutaway schematic view of a vehicle **10**A provided in the form of an HEV according to an exemplary embodiment. A battery system **20**A is provided toward the rear of the vehicle **10**A proximate a fuel tank **12** (the battery system **20**A may be provided immediately adjacent the fuel tank **12** or may be provided in a separate compartment in the rear of the vehicle **10**A (e.g., a trunk) or may be provided elsewhere in the vehicle **10**A). An internal combustion engine **14** is provided for times when the vehicle **10**A utilizes gasoline power to propel the vehicle **10**A. An electric motor **16**, a power split device **17**, and a generator **18** are also provided as part of the vehicle drive system.

[0042] Such a vehicle **10**A may be powered or driven by just the battery system **20**A, by just the engine **14**, or by both the battery system **20**A and the engine **14**. It should be noted that other types of vehicles and configurations for the vehicle drive system may be used according to other exemplary embodiments, and that the schematic illustration of FIG. **2** should not be considered to limit the scope of the subject matter described in the present application.

[0043] According to various exemplary embodiments, the size, shape, and location of the battery systems **20**, **20**A, the type of vehicles **10**, **10**A, the type of vehicle technology (e.g., EV, HEV, PHEV, etc.), and the battery chemistry, among other features, may differ from those shown or described.

[0044] Referring now to FIGS. **3-4**, partial cutaway views of a battery system **21** are shown according to an exemplary embodiment. According to an exemplary embodiment, the battery system **21** is responsible for packaging or containing electrochemical batteries or cells **24**, connecting the electrochemical cells **24** to each other and/or to other components of the vehicle electrical system, and regulating the electrochemical cells **24** and other features of the battery system **21**. For example, the battery system **21** may include features that are responsible for monitoring and controlling the electrical performance of the battery system **21**, managing the thermal behavior of the battery system **21**, containing and/or routing of effluent (e.g., gases that may be vented from a cell **24**), and other aspects of the battery system **21**.

[0045] According to the exemplary embodiment as shown in FIGS. **3-4**, the battery system **21** includes a cover or housing **23** that encloses the components of the battery system **21**. Included in the battery system are two battery modules **22** located side-by-side inside the housing **23**. According to other exemplary embodiments, a different number of battery modules **22** may be included in the battery system **21**, depending on the desired power and other characteristics of the battery system **21**. According to other exemplary embodiments, the battery modules **22** may be located in a configuration other than side-by-side (e.g., end-to-end, etc.).

[0046] As shown in FIGS. **3-4**, the battery system **21** also includes a high voltage connector **28** located at one end of the battery system **21** and a service disconnect **30** located at a second end of the battery system **21** opposite the first end according to an exemplary embodiment. The high voltage connector **28** connects the battery system **21** to a vehicle **10**. The service disconnect **30**, when actuated by a user, disconnects the two individual battery modules **22** from one another, thus lowering the overall voltage potential of the battery system **21** by half to allow the user to service the battery system **21**.

[0047] According to an exemplary embodiment, each battery module **22** includes a plurality of cell supervisory controllers (CSCs) **32** to monitor and regulate the electrochemical cells **24** as needed. According to other various exemplary embodiments, the number of CSCs **32** may differ. The CSCs **32** are mounted on a member shown as a trace board **34** (e.g., a printed circuit board). The trace board **34** includes the necessary wiring to connect the CSCs **32** to the individual electrochemical cells **24** and to connect the CSCs **32** to the battery management system (not shown) of the battery system **21**. The trace board **34** also includes various connectors to make these connections possible (e.g., temperature connectors, electrical connectors, voltage connectors, etc.).

[0048] Still referring to FIGS. **3-4**, each of the battery modules **22** includes a plurality of electrochemical cells **24** (e.g., lithium-ion cells, nickel-metal-hydride cells, lithium polymer cells, etc., or other types of electrochemical cells now known or hereafter developed). According to an exemplary embodiment, the electrochemical cells **24** are generally cylindrical lithium-ion cells configured to store an electrical charge. According to other exemplary embodiments, the electrochemical cells **24** could have other physical configurations (e.g., oval, prismatic, polygonal, etc.). The capacity, size, design, and other features of the electrochemical cells **24** may also differ from those shown according to other exemplary embodiments.

[0049] Each of the electrochemical cells **24** are electrically coupled to one or more other electrochemical cells **24** or other components of the battery system **21** using connectors provided in the form of bus bars **36** or similar elements. According to an exemplary embodiment, the bus bars **36** are housed or contained in bus bar holders **37**. According to an exemplary embodiment, the bus bars **36** are constructed from a conductive material such as copper (or copper alloy), aluminum (or aluminum alloy), or other suitable material. According to an exemplary embodiment, the bus bars **36** may be coupled to terminals **38**, **39** of the electrochemical cells **24** by welding (e.g., resistance welding) or through the use of fasteners **40** (e.g., a bolt or screw may be received in a hole at an end of the bus bar **36** and screwed into a threaded hole in the terminal **38**, **39**).

[0050] Referring now to FIGS. **5-8**, a portion of a battery module **22** for use in a battery system **21** is shown according to an exemplary embodiment. The battery module **22** includes a plurality of electrochemical cells **24** provided in a first member or tray **42** (e.g., structure, housing, etc.). Although illustrated in FIG. **5** as having a particular number of electrochemical cells **24** (i.e., three rows of electrochemical cells arranged such that **14** electrochemical cells are arranged in each row, for a total of **42** electrochemical cells), it should be noted that according to other exemplary embodiments, a different number and/or arrangement of electrochemical cells **24** may be used in the battery module **22** depending on any of a variety of considerations (e.g., the desired power for the battery module **22**, the available space within which the battery module **22** must fit, etc.).

[0051] According to an exemplary embodiment, the tray **42** receives the individual electrochemical cells **24** in the proper orientation for assembling the battery module **22**. According to an exemplary embodiment, the tray **42** may also include features to provide spacing of the cells away from the bottom of the tray and/or from adjacent cells. For example, according to an exemplary embodiment, the trays may include a series of features shown as sockets **44** (e.g., openings, apertures, etc.) to locate and hold the electrochemical cells **24** in position above the bottom of the tray **42**.

[0052] As shown in FIGS. **5-8**, according to another exemplary embodiment, the tray **42** may also include features shown as bosses **46** that are intended to aid in the retention of a housing or cover (not shown) to enclose and/or retain the plurality of cells **24**. According to another exemplary embodiment, the bosses **46** may also aid in securing the tray **42** to the vehicle. According to an exemplary embodiment, the tray **42** may be made of a polymeric material or other suitable material (e.g., electrically insulated material).

[0053] According to an exemplary embodiment, the sockets **44** of the tray **42** are configured to receive (e.g., retain, hold, position, etc.) a lower end or portion of the individual electrochemical cells **24**. According to an exemplary embodiment, the sockets **44** are generally circular openings having at least one step or surface **48** (e.g., as shown in FIG. **9**A) configured to receive the lower portion of the electrochemical cell **24**. According to other exemplary embodiments, the openings of the sockets **44** may have other shapes to receive cells of different shapes (e.g., prismatic, oval, etc.). The lower steps or surface **48** of the socket **44** positions the electrochemical cell **24** at a top portion of an airspace or chamber **50** defined by the tray **42** (e.g., as shown in FIG. **9**). The chamber **50** is configured to receive gases and/or effluent that may be vented by the electrochemical cells **24** through a vent feature or vent device (e.g., vent **52** as shown in FIG. **9**) of the electrochemical cell **24**.

[0054] Referring now to FIGS. **7**, **9**, and **9**A, the battery module **22** may also include a member shown as a gasket or seal **54**. According to an exemplary embodiment, the seal **54** is configured to aid in sealing the lower portions of the electrochemical cells **24** in the tray **42** to help retain any gases vented from the electrochemical cells **24** into the chamber **50**. According to an exemplary embodiment, the seal **54** is provided adjacent a top surface of the tray **42**. According to an exemplary embodiment, the seal **54** may be constructed from a pliable, non-conductive material such as silicone. According to another exemplary embodiment, the seal **54** may be die cut from a silicone sheet or may be a molded silicone member (e.g., made by an injection molding process). According to another exemplary embodiment, the seal may be any seal that is shown and described in International Patent Application No. PCT/US2009/053697, filed Aug. 13, 2009, the entire disclosure of which is incorporated herein by reference. According to other exemplary embodiments, the seal may be any seal that is now known or developed in the future.

[0055] According to an exemplary embodiment, a member (fixture, device, plate, retainer, etc.) shown as a clamping plate **56** may be provided above the seal **54** in order to keep the seal **54** in place in relation to the tray **42**. The clamping plate **56** may be coupled to the tray **42**, for example, by threaded fasteners (not shown) that extend through holes **58** in the clamping plate **56** and are received by threaded holes **60** in the tray **42**. According to another exemplary embodiment, the clamping plate **56** may be coupled to the tray **42** via a snap fit.

[0056] According to an exemplary embodiment, the seal **54** includes a plurality of openings **62** that align with the plurality of sockets **44** of the tray **42**. As shown in FIG. **9**A, each of the openings **62** of the seal **54** comprise a lip portion or edge portion **64** (e.g., a deformable extension) provided in contact with an electrochemical cell **24**. According to an exemplary embodiment, the edge portion **64** of the seal **54** is angled in toward the electrochemical cell **24** to provide an interference fit with the electrochemical cell **24** in order to aid in sealing the chamber **50**.

[0057] According to an exemplary embodiment, the edge portion **64** of the seal **54** is thinner than the rest of the seal **54**, giving the edge portion flexibility to conform to the outer diameter of the electrochemical cell **24** in order to aid in sealing in the electrochemical cell **24**. According to another exemplary embodiment, the edge portion **64** of the seal **54** is tapered (e.g., as shown in FIG. **9**A) from the main portion **66** of the seal **54** down to the tip **68** of the edge portion **64**. This taper aids in giving the edge portion **64** the flexibility to conform to the outer diameter of the electrochemical cell **24** but still maintain the strength to allow the edge portion **64** to keep its shape over time (e.g., to minimize creep and relaxation of the seal **54** to maintain the interference fit with the electrochemical cell **24**).

[0058] According to an exemplary embodiment, a space **70** is provided between the edge portion **64** of the seal **54** and each socket **44** of the tray **42** (e.g., as shown in FIG. **9**A). The space **70** is connected (e.g., in fluid communication) with the chamber **50** such that when gases are vented into the chamber **50** the gases may enter the space **70** (e.g., by slipping past the bottom of the electrochemical cell **24** and the socket **44**). According to an exemplary embodiment, the vented gases press the seal **54** tighter against the electrochemical cell **24** to increase the sealing characteristics of the seal **54**.

[0059] Referring now to FIGS. **10**-**10**B, a portion of a cell **124** is shown according to another exemplary embodiment. The cell **124** includes a can or housing **126** having a generally cylindrical main body (i.e., walls) and a bottom **130** at one end thereof (although this end is referred to with respect to this and other embodiments herein as "bottom," it should be understood that this could also be a "top" or "side" according to other configurations and/or depending on how the cell is oriented in a given application). The housing **126** also includes a top portion or cover (not shown) at an end of the housing **126** opposite the bottom **130**. The housing **126** is configured to receive a cell element **125** (e.g., a wound, cylindrical cell element).

[0060] According to an exemplary embodiment, a member such as an insulator (e.g., shown as an O-ring insulator **134** in FIG. **10**, a square-ring insulator **334** in FIG. **11**, or a thin insulator **434** (e.g., an L-shaped insulator in cross-section) in FIG. **12**A) may be provided between the cell element **125** and the bottom **130** of the housing **126**. According to an exemplary embodiment, the insulator may be made from polypropylene. According to other exemplary embodiments, the insulator may be made from any suitable material including other suitable polymeric materials. According to another exemplary embodiment, the cell **124** may also include a thin insulator wrap (not shown) provided around the exterior of the cell element **125** in between the cell element **125** and the housing **126**. According to an exemplary embodiment, the insulator and/or the insulator wrap conductively insulate the cell element **125** from the housing **126**.

[0061] According to an exemplary embodiment, a current collector (such as, e.g., positive current collector **132** shown in FIG. **10**, although a negative current collector could be used according to other exemplary embodiments) is provided between an end of the cell element **125** and the bottom **130** of the housing **126**. According to an exemplary embodiment, a first side of the current collector **132** is coupled (e.g., welded) to the end of the cell element **125** and a second side of the current collector **132** is coupled (e.g., welded) to the bottom **130** of the housing **126**. For example, the current collector **132** may be laser welded to the bottom **130** of the housing in a circular pattern (e.g., such as shown by weld **148** in FIG. **10**B). However, according to other exemplary embodiments, the current collector **132** may be coupled to the bottom **130** in a different manner. The current collector **132** provides a conductivity path for current flow from the cell element **125** to the housing **126**. According to another exemplary embodiment, the housing **126** may be conductively coupled to a cell terminal (not shown).

[0062] According to an exemplary embodiment, the cell **124** includes a vent (such as, e.g., vent **152** shown in FIG. **10**). The vent **152** is configured to allow gases and/or effluent to exit the cell **124** once the pressure inside the cell reaches a predetermined amount (e.g., during a rise in cell temperature). When the vent **152** deploys (e.g., activates, opens, separates, etc.), the gases and/or effluent (represented by arrows **149** in FIG. **10**A) inside the cell **124** exit the cell **124** to lower the pressure inside the cell **124**. According to an exemplary embodiment, the vent **152** acts as a safety device for the cell **124** during a high pressure occurrence.

[0063] According to an exemplary embodiment, the vent **152** is located in the bottom **130** of the housing **126**. According to other exemplary embodiments, the vent **152** may be located elsewhere (e.g., side of the housing, cover, etc.). According to another exemplary embodiment, the vent **152** may be located in a cover or bottom that is a separate component that is then coupled (e.g., welded) to the housing **126**.

[0064] According to an exemplary embodiment, the bottom **130** of the housing **126** may include at least one ridge, projection, or ring of material (such as, e.g., projection **128** shown in FIG. **10**) extending outward from the bottom of the cell. The projection **128** is configured to prevent premature deployment of the vent **152** during handling and/or assembly of the cell **124**. The projection **128** provides for a clearance space between the vent **152** and a surface that the cell **124** is set upon. According to an exemplary embodiment, the clearance space is configured to prevent the vent **152** from being accidentally bumped (and deployed) during handling and/or assembly of the cell **124**.

[0065] As shown in FIGS. **10**-**10**B, according to one exemplary embodiment, the projection **128** is shown as a continuous ring (e.g., a raised circular ring). However, according to other exemplary embodiment, the projection **128** may not be continuous (i.e., the projection **128** may be discontinuous). For example, the projection **128** may include multiple projections, such as, for example, multiple curved or arcuate projections. The multiple curved projections (or other type of projections) may or may not be equally spaced along the bottom **130**, according to various exemplary embodiments. According to other exemplary embodiments, the projections may be not be curved.

[0066] As shown in FIGS. **10**-**10**B, the vent **152** includes at least one annular or circular groove **140** (ring, trough, pressure point, fracture point, fracture ring, etc.). According to one exemplary embodiment, the vent **152** also includes a second annular or circular groove **142**. As shown in FIG. **10**, the outer groove **142** has an upside down V-shaped configuration. According to one exemplary embodiment, the vent **152** is configured to break away (i.e., separate) from the bottom **130** of the housing **126** at the outer groove **142** when the vent **152** deploys. According to other exemplary embodiments, the bottom of the outer groove **142** may have another shape and/or configuration (e.g., rounded shape, curved shape, upside down U-shape, etc.). Also as shown in FIG. **10**, the inner groove **140** has a rounded or curved configuration. According to one exemplary embodiment, the vent **152** is configured to bend at the inner groove **140** when the vent **152** deploys. According to other exemplary embodiments, the bottom of the inner groove **140** may have another shape and/or configuration (e.g., upside down V-shape, upside down U-shape, etc.).

[0067] As stated earlier, the vent **152** is configured to deploy once the pressure inside the cell **124** reaches a predetermined amount. When the vent **152** deploys, the outer groove **142** fractures and a flexible portion **146** of the vent **152** separates from the bottom **130** of the housing **126** (e.g., as shown in FIG. **10**A). The inner groove **140** aids the outer groove **142** in fracturing by allowing the flexible portion **146** to bend or fold away from the bottom **130** at a center portion **144** of the bottom **130**. According to one exemplary embodiment, the center portion **144** remains in contact with the flexible portion **146**. According to another exemplary embodiment, the center portion **144** also separates from the flexible portion **146**. According to another exemplary embodiment, the vent **152** may be configured to fracture at the inner groove **140**, allowing the flexible portion **146** to separate from the center portion **144**. In this embodiment, the outer groove **142** is configured to allow the flexible portion **146** to bend or fold away from the bottom **130** during deployment of the vent **152**.

[0068] By having the vent **152** separate from the bottom **130** of the housing **126**, the vent **152** acts as a current interrupt or current disconnect device. This is because the separation of the vent **152** from the bottom **130** of the housing **126** disrupts the flow of current from the cell element **125** (through the current collector **132**) to the housing **126**. In this way, the vent **152** acts not only as an over-pressure safety device, but also as a current disconnect device.

[0069] According to an exemplary embodiment, radial scoring **150** may be provided in between the outer groove **142** and inner groove **140** of the vent **152** (e.g., as shown in FIG. **10**B) to help the vent **152** flex or bend (e.g., collapse upon itself) when the vent **152** deploys. According to one exemplary embodiment, the radial scoring **150** is provided as a rounded or curved groove or indentation, although other shapes (e.g., a V-shaped groove) may also be used. According to another exemplary embodiment, a support or post (such as, e.g., post **63** shown in FIG. **9**) may be provided below the vent **152** to aid the vent **152** to deploy (e.g., around the support or post). For example, according to one exemplary embodiment, the post **63** may be provided below the center portion **144** to add support to or increase the rigidity of the vent **152** when the flexible portion **146** separates from the bottom **130** (either at the inner groove **140** or the outer groove **142**).

[0070] According to one exemplary embodiment, the cell element **125** does not move during deployment of the vent **152** (i.e., the cell element remains stationary). According to other exemplary embodiments, the cell element **125** may move within the housing **126** to help deploy the vent **152** (e.g., by "pushing" or "punching" the current collector through the vent). According to one exemplary embodiment, the cell element **125** moves (e.g., toward the vent **152**) within the housing **126** due to an increase in pressure within the housing **126**.

[0071] Referring now to FIG. **10**C, a bottom of an electrochemical cell is shown according to another exemplary embodiment. According to an exemplary embodiment, the cell **224** includes features similar to that shown in FIGS. **10**-**10**B, but for a prismatic shaped cell (with similar features as shown in FIGS. **10**A-**10**B labeled with corresponding reference numbers in the **200** series). The features of cell **224** may function similarly to those shown and described above in regard to FIGS. **10**-**10**B, but are sized and/or shaped according to a prismatic configuration.

[0072] Referring now to FIG. **11**, an electrochemical cell **324** is shown according to another exemplary embodiment. According to an exemplary embodiment, the electrochemical cell **324** includes features similar to those shown in FIGS. **10**-**10**B (with the features labeled with corresponding reference numbers in the **300** series), but with a square-ring insulator **334** (i.e., an annular insulator having a square cross-section). The square-ring insulator **334** performs functionally similar to the O-ring insulator **134** shown in FIGS. **10**-**10**B. According to still other exemplary embodiments, insulators having other cross-sectional shapes and/or sizes are possible (e.g., oval, rectangular, etc.).

[0073] Referring now to FIG. **12**A, an electrochemical cell **424** is shown according to another exemplary embodiment. According to an exemplary embodiment, the electrochemical cell **424** includes a vent **452** similar to the vent shown in FIGS. **10**-**10**B (with similar features to those in FIGS. **10**-**11** labeled with corresponding reference numbers in the **400** series).

[0074] According to an exemplary embodiment, the electrochemical cell **424** also includes a cell element **425** located in a housing **426**. As shown, the electrochemical cell **424** also includes a thin or low-profile insulator **434** provided between the cell element **425** and the cell housing **426** to electrically insulate the cell element **425** from the cell housing **426**. According to an exemplary embodiment, the thin insulator **434** has an L-shaped cross-section and extends in a first direction along a side of the cell element **425** and in a second direction along a bottom of the cell element **425**.

[0075] According to other exemplary embodiments, the thin insulator **434** may have a different cross-section and/or other configuration (e.g., the insulator may be two separate components, the insulator may extend only along the edge (or the bottom) of the cell element **425**, the insulator may extend all the way along the edge of the cell element **425** from the top of the cell element **425** to the bottom of the cell element **425**, etc.).

[0076] According to another exemplary embodiment, the cell element **425** may have a thin insulator wrap (not shown) provided around the exterior of the cell element **425** in between the cell element **425** and the housing **426**. According to this exemplary embodiment, the cell **424** may also include a thin insulator (e.g., ring, washer, etc.) (not shown) provided at the bottom of the cell element **425** between the cell element **425** and the bottom **430** of the housing **426**. According to an exemplary embodiment, the thin insulator is part of the insulator wrap provided around the exterior of the cell element **425**. According to another exemplary embodiment, the thin insulator is a separate component.

[0077] According to the exemplary embodiment shown in FIG. **12**A, the electrochemical cell **424** further includes a current collector **432** that is electrically coupled (e.g., welded) to an end of the cell element **425** and to a bottom **430** of the housing **426** (e.g., to a center portion **444** of the vent **452** as shown in FIG. **12**A). The current collector **432** is thinner than the current collector **132** shown in FIG. **10**. Such a configuration may be used in particular in configurations where the cell element does not need to move in order to deploy the vent (e.g., the vent is pressure activated). Because the current collector **432** (and the insulator **434**) is thin, more space within the housing **426** can be used for the cell element **425**, allowing the cell **424** to have a higher power density.

[0078] Referring now to FIGS. **12**B-**12**J, various configurations of vents for an electrochemical cell are shown according to a number of exemplary embodiments. The features of the cells (with the exception of the vents) shown FIGS. **12**B-**12**J are similar to the features as described above with respect to FIG. **12**A (with similar features as shown in FIG. **12**A labeled with reference numbers in the **500** series for FIG. **12**B, **600** series for FIG. **12**C, **700** series for FIG. **12**D, **800** series for FIG. **12**E, **900** series for FIG. **12**F, **1000** series for FIG. **12**G, **1100** series for FIG. **12**H, **1200** series for FIGS. **121**, and **1300** series for FIG. **12**J).

[0079] As shown in FIGS. **12**B-**12**J, the inner and outer fracture grooves may have various shapes, sizes, and/or configurations. For example, the inner grooves may have a relatively wide profile (such as shown in FIG. **12**B), a relatively tall profile (such as shown in FIG. **12**F), or a pointed profile (such as shown in FIGS. **12**G-**12**J). Additionally, for example, the outer grooves may have a short profile (such as shown in FIGS. **12**C, **12**G, and **12**J), or a curved or rounded profile (such as shown in FIGS. **12**C-**12**F). According to other exemplary embodiments, many other shapes, sizes, and/or configurations of fracture grooves are possible.

[0080] As shown in FIG. **12**B, according to an exemplary embodiment, inner groove **540** has a rounded (e.g., semi-circular, arcuate, curved, etc.) configuration while outer groove **542** has a V-shaped configuration. As shown in FIG. **12**C, according to an exemplary embodiment, both the inner groove **640** and the outer groove **642** have a relatively shallow rounded configuration. Alternatively, as shown in FIG. **12**D, according to an exemplary embodiment, both the inner groove **740** and the outer groove **742** have a relatively large (e.g., deep) rounded configuration.

[0081] As shown in FIG. **12**E, according to an exemplary embodiment, inner groove **840** has a relatively shallow circular or rounded configuration while outer groove **842** has a relatively large (e.g., deep) rounded configuration. In FIG. **12**F, inner groove **940** has a relatively large (e.g., deep) rounded configuration while outer groove **942** has a relatively shallow rounded configuration.

[0082] According to another exemplary embodiment, as shown in FIG. **12**G, both the inner groove **1040** and the outer groove **1042** have a relatively shallow V-shaped configuration. Alternatively, as shown in FIG. **12**H, both the inner groove **1140** and the outer groove **1142** have a relatively large (e.g., deep) V-shaped configuration.

[0083] As shown in FIG. **121**, according to an exemplary embodiment, inner groove **1240** has a relatively shallow V-shaped configuration while outer groove **1242** has a relatively large (e.g., deep) V-shaped configuration. Alternatively, as shown in FIG. **12**J, inner groove **1340** has a relatively large (e.g., deep) V-shaped configuration while outer groove **1342** has a relatively shallow V-shaped configuration.

[0084] Referring now to FIGS. **13**-**21**, an electrochemical cell **1424** is shown according to another exemplary embodiment. As shown in FIG. **13**, the electrochemical cell **1424** includes a can or housing **1426**, a bottom portion **1430** located at a first end of the housing **1426** and a cover **1460** located at a second end of the housing **1426**. The electrochemical **1424** also includes a first terminal (e.g., positive terminal **1462**) and a second terminal (e.g., negative terminal **1464**) coupled to the cover **1460** of the electrochemical cell **1424**. As shown in FIG. **14**, each terminal **1462**, **1464** includes a threaded hole **1463**, **1465** that is configured to receive a fastener to secure a buss bar thereto.

[0085] Also shown in FIG. **14**, according to an exemplary embodiment, ridges or projections **1468**, **1469** are configured to add strength and/or rigidity to the cover **1460** for when the cover **1460** is coupled (e.g. welded) to the housing **1426**. The ridges **1468**, **1469** may be curved or rounded as shown in FIG. **14** or may be otherwise configured (e.g., straight, squared, etc.). The cover **1460** also includes a fill hole and plug **1479** configured to allow electrolyte to be provided inside the housing **1426**. The fill hole and plug **1479** may be located in a spot other than that is shown in FIG. **14** (such as, e.g., on the housing **1426**, on the bottom portion **1430**, etc.).

[0086] FIG. **15** shows a bottom view of the electrochemical cell **1424** according to one exemplary embodiment. In this exemplary embodiment, the electrochemical cell **1424** is a cylindrical cell. According to other exemplary embodiments, the electrochemical cell **1424** may have a different shape. For example, as shown in FIG. **15**A, the electrochemical cell **1424** may have a prismatic shape. According to still other exemplary embodiments, the electrochemical cell **1424** may have other shapes (e.g., hexagonal, oval, etc.). The features of FIGS. **15** and **15**A (as will be described below in more detail) have similar functions; therefore the features shown in FIG. **15**A have corresponding reference numbers to FIG. **15** but followed by a letter "A."

[0087] As shown in FIG. **16**, according to an exemplary embodiment, the cover **1460** is electrically and conductively coupled (e.g., welded) to the housing **1426**. The positive terminal **1462** is electrically and connectively coupled to the cover **1460**. According to one exemplary embodiment, the positive terminal **1462** is provided within a socket or recess **1461** provided in the cover **1460**. According to one exemplary embodiment, the recess **1461** and the positive terminal **1462** are configured for an interference fit. According to another exemplary embodiment, the positive terminal **1462** is laser welded to the cover **1460** after the positive terminal **1462** has been provided within recess **1461** (with or without an interference fit between the positive terminal **1462** and the recess **1461**).

[0088] According to the exemplary embodiment shown in FIG. **16**, the negative terminal **1464** is provided with an aperture or hole of the cover **1460** and is electrically insulated from the cover **1460** by a insulating member (e.g., insulators **1467**A and **1467**B). According to one exemplary embodiment, as shown in FIG. **16**, the insulators **1467**A, **1467**B are two separate components. However, according to another exemplary embodiment, the insulating member may be a single unitary member (i.e., one piece).

[0089] As shown in FIG. **16**, the negative terminal **1464** is held in place within the aperture or hole of the cover **1460** by the geometry of the negative terminal **1464** on one side and a member or washer **1466** on the opposite side of the negative terminal **1464**. As shown in FIG. **16**, according to one exemplary embodiment, the negative terminal **1464** is deformed as shown by projection or deformation **1471**, which holds the negative terminal **1464**, the insulator **1467**A, **1467**B, and the washer **1466** in place.

[0090] According to an exemplary embodiment, the negative terminal **1464** is electrically and conductively coupled (e.g., welded) to a negative electrode of the electrochemical cell **1424** by a current collector (such as, e.g., negative current collector **1470** as shown in FIG. **16**). The negative electrode, together with a positive electrode, form a cell element **1425** (e.g., a wound cell element) that is provided within the housing **1426** of the electrochemical cell **1424**. A mandrel **1472** may be provided to wind the negative and positive electrodes around the mandrel **1472** to form the cell element **1425**. According to another exemplary embodiment, the mandrel **1472** may not be required (e.g., such as on a prismatic cell, as shown in FIG. **15**A).

[0091] As shown in FIG. **16**, according to an exemplary embodiment, an insulating member such as insulator **1469** is provided below the cover **1460** (e.g., in an area generally underneath the positive terminal **1462**) to insulate the cover **1460** from the negative terminal **1464**, negative current collector **1470**, and negative electrode of the cell element **1425**. According to other exemplary embodiments, the insulator **1469** may have other shapes and/or sizes. According to another exemplary embodiment, the insulator **1469** is not included with the cell **1424**.

[0092] According to one exemplary embodiment, the positive terminal **1462** comprises aluminum (e.g., aluminum alloy) or other suitable material. According to one exemplary embodiment, the negative terminal **1464** comprises copper (e.g., copper alloy) or other suitable material. Both the positive terminal **1462** and the negative terminal **1464** may be coated or plated with a nickel material, according to one exemplary embodiment. According to one exemplary embodiment, the insulators **1467**A, **1467**B and **1469** may be constructed from any suitable electrically insulating material. For example, the insulators may be constructed from a polyetherimide (e.g., such as ULTEM®, commercially available from SABIC Innovative Plastics of Riyadh, Saudi Arabia) or other suitable polymer material. The washer **1467** may be made from a suitable material, such as stainless steel. According to an exemplary embodiment, the housing **1426**, the cover **1460**, and the bottom **1430** may be constructed from aluminum (or aluminum alloy) or other suitable material.

[0093] Referring now to FIG. **17**, a bottom portion of the cell **1424** is shown according to an exemplary embodiment. As shown in FIG. **17**, the housing **1426** includes a vent **1452**. The vent **1452** is configured to allow gases and/or effluent to exit the cell **1424** once the pressure inside the cell **1424** reaches a predetermined amount (e.g., during a rise in cell temperature). When the vent **1452** deploys (e.g., activates, opens, separates, etc.), the gases and/or effluent inside the cell **1424** exit the cell **1424** in order to lower the pressure inside the cell **24** (e.g., as represented by arrows **1449** shown in FIG. **17**A). According to an exemplary embodiment, the vent **1452** acts as a safety device for the cell **1424** during a high pressure occurrence.

[0094] According to an exemplary embodiment, the vent **1452** is located in a bottom **1430** (or bottom portion) of the housing **1426**. According to other exemplary embodiments, the vent **1452** may be located elsewhere (e.g., such as in the lid or cover of the cell). According to another exemplary embodiment, the vent **1452** may be located in a cover or bottom that is a separate component from the housing **1426** that in turn is coupled to the housing **1426** (e.g., by a welding operation).

[0095] According to the exemplary embodiment shown in FIG. **17**, the housing **1426** and the bottom **1430** are formed as a single component (i.e., a single unitary member). According to an exemplary embodiment, the housing **1426** (with the bottom **1430**) is formed by a deep drawing operation. However, according to other exemplary embodiments, the housing **1426** and the bottom **1430** may be separate components that are then coupled (e.g., welded) together.

[0096] According to the exemplary embodiment shown, the vent **1452** is coupled to the bottom **1430** by a weakened area shown as notch or groove **1440** (e.g., ring, trough, pressure point, fracture point, fracture ring, etc.). According to an exemplary embodiment, the vent **1452** is configured to break away (i.e., separate) from the bottom of the housing **1426** at the notch **1440** when the vent **1452** deploys (as will be described below in more detail with respect to FIG. **17**A). According to an exemplary embodiment, the vent **1452** is formed by a stamping operation, a machining operation, or any other suitable operation.

[0097] The bottom **1430** also includes a generally flat area **1431** that is configured for mating with a seal provided as part of the battery module in which the electrochemical cell **1424** is provided. Such a seal may be a seal that is shown and described in International Patent Application No. PCT/US2009/053697, filed Aug. 13, 2009, the entire disclosure of which is incorporated herein by reference. Additionally, the generally flat area **1431** is configured to allow for an area of the electrochemical cell **1424** specifically for handling and transporting the cell **1424** without worry of prematurely deploying the vent **1452**.

[0098] The bottom **1430** also includes a feature shown as a ridge or projection **1428** (e.g., protrusion, ring of material, etc.) provided adjacent an inner edge of the flat area **1431**. According to an exemplary embodiment, the projection **1428** is configured to extend out and away from the bottom **1430** of the housing **1426** (e.g., the flat area **1431**) such that the projection **1428** is the lowest point of the cell **1424**. As such, the projection **1428** is configured to prevent any accidental or premature deployment of the vent **1452**. For example, the projection **1428** provides for a clearance space between the vent **1452** and a surface that the cell **1424** is set upon. According to an exemplary embodiment, the clearance space is configured to prevent the vent **1452** from being accidentally bumped (and deployed) during handling and/or assembly of the cell **1424**.

[0099] As shown in FIGS. **15** and **17**, according to one exemplary embodiment, the projection **1428** is shown as a continuous ring (e.g., a raised circular ring). However, according to other exemplary embodiment, the projection **1428** may not be continuous (i.e., the projection **1428** may be discontinuous). For example, the projection **1428** may include multiple projections, such as, for example, multiple curved or arcuate projections. The multiple curved projections (or other type of projections) may or may not be equally spaced along the bottom **1430**, according to various exemplary embodiments. According to other exemplary embodiments, the projections may be not be curved.

[0100] As shown in FIGS. **17** and **17**A, the electrochemical cell **1424** also includes a current collector (e.g., a positive current collector **1432**). An example of such a current collector is shown and described in International Patent Application No. PCT/US2009/065365, filed on Nov. 20, 2009, the entire disclosure of which is hereby incorporated by reference. According to other exemplary embodiments, the current collector **1432** may be a negative current collector.

[0101] As shown in FIGS. **17** and **17**A, a first side of the positive current collector **1432** is conductively coupled to a positive electrode of the cell element **1425** and a second side of the positive current collector **1432** is conductively coupled to a center portion **1444** of the vent **1452**. Specifically, the positive current collector **1432** includes a center portion **1433** that is electrically and conductively coupled (e.g., welded) to the vent **1452**. According to one exemplary embodiment, the center portion **1433** of the positive current collector **1432** is laser welded to the center portion **1444** of the vent **1452**. For example, the center portion **1433** may be laser welded such as shown in FIG. **15** (i.e., a circular laser weld **1448**). However, according to other exemplary embodiments, the positive current collector may be otherwise coupled to the vent **1452**.

[0102] The positive current collector **1432** also includes flexible members or arms **1435** that are coupled at one end to the center portion **1433** of the positive current collector **1432** and at a second end to an outer portion **1436** of the positive current collector **1432**. The outer portion **1436** of the positive current collector **1432** is electrically or conductively coupled (e.g., welded) to the positive electrode of the cell element **1425**.

[0103] As shown in FIGS. **17** and **17**A, the electrochemical cell **1424** also includes an insulating member shown as insulator **1434** provided between the positive current collector **1432** and the housing **1426** to electrically insulate the positive current collector **1432** from the housing **1426**. According to an exemplary embodiment, the insulator **1434** extends in a first direction along a side of the cell element **1425** and in a second direction along a bottom of the cell element **1425**. According to other exemplary embodiments, the insulator **1434** may be otherwise configured (e.g., the insulator may be two separate components, the insulator may extend only along the edge (or the bottom) of the cell element **1425**, the insulator may extend all the way along the edge of the cell element **1425** from the top of the cell element **1425** to the bottom of the cell element **1425**, etc.).

[0104] As shown in FIG. **17**A, the vent **1452** is in a deployed state. The vent **1452** has broken or fractured from the bottom **1430** of the housing **1426** at the notch **1440** to allow gas and/or effluent (represented by arrows **1449**) to exit the electrochemical cell **1424**. The flexible arms **1435** allow the positive current collector **1432** to flex (i.e., moved downward) when the vent **1452** is deployed.

[0105] According to one exemplary embodiment, the cell element **1425** does not move during deployment of the vent **1452** (i.e., the cell element remains stationary and only the flexible arms **1435** and the vent **1452** move). According to such exemplary embodiments, flexible current collectors (such as current collector **1432**) may be utilized. According to other exemplary embodiments, the cell element **1425** may move to help deploy the vent **1452** (e.g., by "pushing" or "punching" the current collector through the vent). According to such exemplary embodiments, non-flexible current collectors may be utilized.

[0106] When the vent **1452** detaches from the housing **1426**, the path of current flow from the positive electrode to the housing **1426** (via the positive current collector **1432**) is interrupted since the vent **1452** separates from the housing **1426** at the notch **1440**. By having the vent **1452** separate from the bottom **1430** of the housing **1426**, the vent **1452** acts as a current interrupt or current disconnect device. This is because the separation of the vent **1452** from the bottom **1430** of the housing **1426** disrupts the flow of current from the cell element **1425** (through the positive current collector **1432**) to the housing **1426**. In this way, the vent **1452** acts not only as an over-pressure safety device, but also as a current disconnect device.

[0107] As shown in FIGS. **18-21**, the vent **1452** includes various features to help ensure that the vent **1452** evenly and completely detaches from the housing **1426** as the vent **1452** is deployed (e.g., to ensure current interruption). One such feature of the vent **1452** is the increased relative thickness of the vent **1452** as compared to the thickness of the housing wall (e.g., such as shown in FIG. **19**). The increased relative thickness of the vent **1452** adds extra mass to the vent **1452** to help in deploying the vent **1452** after the vent **1452** has initially broken at one point of the notch **1440**.

[0108] It is noted that the relatively thick vent **1452** may include a recessed area **1443** at the center of the vent **1452** (e.g. as shown in FIG. **18**). The recessed area **1443** aides in proper laser welding of the current collector (for example, the positive current collector **1432**) to the vent **1452**. The recessed area **1443** transitions to the regular thickness of the vent **1452** at a step **1445** of the center portion **1444** of the vent **1452**. According to one exemplary embodiment, the step **1445** has a generally square transition (e.g., corner) between the center portion **1444** and the step **1445** and a generally rounded transition between the recessed portion **1443** and the step **1445**. However, according to other exemplary embodiment, the transition **1445** may have other shapes and/or sizes.

[0109] Another feature of the vent **1452** includes a first angled **1446** (e.g., angular portion, raised portion, elevated portion, etc.) and a second angled **1447** (e.g., angular portion, raised portion, elevated portion, etc.). The angled portions **1446** and **1447** are provided to increase the strength and rigidity of the vent **1452**. According to one exemplary embodiment, the angle (e.g., angle "A" as shown in FIG. **20**) of the first angled portion **1446** is between approximately 0 degrees and 10 degrees. According to another exemplary embodiment, the angle A is approximately 4 degrees. According to one exemplary embodiment the angle of the second angled portion **1447** (e.g., angle "B" as shown in FIG. **20**) is between approximately 0 degrees and 40 degrees. According to another exemplary embodiment, the angle B is between approximately 30 degrees and 40 degrees. However according to other exemplary embodiments, angles A and B may be greater or smaller as required by the desired application. According to another exemplary embodiment, only one of the angled portions may be provided between the notch **1440** and the center portion **1444**.

[0110] In addition to adding strength and rigidity to the vent **1452**, the angled portions **1446**, **1447** allow the vent **1452** to be at a height above the projection **1428**. As noted earlier, this protects the vent **1452** from premature deployment. For example, if the electrochemical cell **1424** is handled too roughly placed on a surface, the lowest portion of the cell (i.e., the projection **1428**) contacts the surface first, thus protecting the vent **1452**.

[0111] Referring now to FIG. **21**, a notch **1440** of the electrochemical cell **1424** is shown according to an exemplary embodiment. The notch **1440** includes a first step or diameter **1441** and a second step or diameter **1442**. The first and second steps **1441**, **1442** are connected by a ledge or surface **1453**. The notch **1440** also includes a tip **1451** located at the top of the notch **1440**. It is at this tip **1451** that the vent **1452** breaks away from the rest of the housing **1426**. Due to the relative thinness of the notch **1440** at the tip **1451**, the vent **1452** cleanly breaks away from the housing **1426**. According to various exemplary embodiments, the tip **1451** of the notch

1440 may have any suitable shape (e.g., rounded shape, curved shape, upside down U-shape, upside down V-shape, etc.).

[0112] As can be seen in FIG. **21**, the notch **1440** is provided relatively close to the projection **1428**. However, according to other exemplary embodiments, the notch **1440** may be located further away from the projection **1428**. According to an exemplary embodiment, the notch **1440** is formed from a 2-stage stamping operation that results in the first and second steps **1441**, **1442**. However, according to other exemplary embodiments, the notch **1440** may be otherwise formed and may or may not have the first and second steps **1441**, **1442**.

[0113] Also shown in FIG. **21** is a rounded surface **1456** that aides in the transition from the relatively thick bottom portion of the housing **1426** (i.e., the portion of the housing comprising the flat area **1431**) to the relatively thin area of the notch **1440**. However, according to other exemplary embodiments, the surface **1456** may be otherwise configured (e.g., straight, square cut, etc.).

[0114] Referring now to FIGS. **21-21**F, a notch is shown according to various exemplary embodiments. The components of each of the notches of FIGS. **21**A-**21**F are represented by reference numbers that increase sequentially (with similar features as shown in FIG. **21** labeled with corresponding reference numbers in the **1500** series for FIG. **21**A, **1600** series for FIG. **21**B, **1700** series for FIG. **21**C, **1800** series for FIG. **21**D, **1900** series for FIG. **21**E, and **2000** series for FIG. **21**F).

[0115] As shown in FIG. **21**A, the notch **1540** includes only a single step **1541**. Notch **1540** is a relatively narrow opening and has a rounded tip **1551**. In contrast, the notch **1640** as shown in FIG. **21**B includes a relatively wide opening and rounded tip **1651**. Alternatively, as shown in FIG. **21**C, a pointed tip **1751** is shown. FIG. **21**D shows a notch **1840** having a first step **1841** and second step **1842** with fairly rounded transitions between the steps **1841** and **1842**.

[0116] According to another exemplary embodiment as shown in FIG. **21**E, notch **1940** includes three steps with a rounded tip **1951**. Alternatively, FIG. **21**F shows a notch **2040** having three steps **2041**, **2042**, **2054** and a pointed tip **2051**. According to other exemplary embodiments, the steps of FIGS. **21**E-**21**F may be more rounded and/or have smoother transitions between the steps. According to other exemplary embodiments, the notches may have a greater or lesser number of steps and/or transitions.

[0117] The notches shown in FIGS. **21-21**F may be formed from a machining operation (e.g., a mill or a lathe) or a stamping operation (e.g., progressive stamping). Because the geometry of the notch is located on the external side of the housing, the notch can be more efficiently created. For example, the tooling tolerance is only affected by one side of the tool, allowing for a more consistent notch, resulting in a more consistent and repeatable opening of the vent. The depth, shape, and size of the notch may be easily modified simply by changing the tooling. Additionally, having the notch located on the exterior side of the housing allows the notch to be much more easily cleaned and inspected prior to assembly within a battery module. For example, the notch may be inspected by a laser (e.g., to measure the size of the notch) from the outside of the cell.

[0118] Referring now to FIG. **22**, a cell housing **2126** having a vent **2152** for an electrochemical cell (e.g., cell **24**) is shown according to another exemplary embodiment. As shown in FIG. **22**, the vent **2152** is provided in a bottom portion **2130** of the housing **2126**. According to other exemplary embodiments, the vent **2152** may be provided elsewhere (e.g., such as in the lid or cover of the cell). According to another exemplary embodiment, the vent **2152** may be located in a cover or bottom that is a separate component from the housing **2126** that in turn is coupled to the housing **2126** (e.g., by a welding operation).

[0119] As shown in FIG. **22**, the vent **2152** includes a center portion **2144** that is coupled to the housing **2126** at a weakened area. For example, the vent **2152** includes at least one annular or circular fracture ring or groove **2140** (e.g., notch, cut, indentation, dimple, channel, trough, pressure point, fracture point, fracture ring, etc.) located near the outer circumference of the bottom **2130**. According to an exemplary embodiment, the annular or circular fracture groove **2140** has a rounded bottom and is configured to break away (i.e., separate) from the bottom of the housing **2126** when the vent **2152** deploys. According to other exemplary embodiments, the bottom of the fracture groove **2140** may have another shape (e.g., curved shape, upside down U-shape, upside down V-shape etc.).

[0120] According to an exemplary embodiment, the bottom of the housing **2126** may include a ridge, projection, or ring of material **2128** to prevent fracture of the vent **2152** during handling and/or assembly of the cell. The projection **2128** provides for a clearance space between the vent **2152** and a surface that the cell is set upon. According to an exemplary embodiment, the clearance space is configured to prevent the vent **2152** from being accidentally bumped (and deployed) during handling and/or assembly of the cell.

[0121] According to an exemplary embodiment, the vent **2152** is formed by tooling located external the housing. The tooling tolerance is only affected by one side of the tool, allowing for a more consistent groove **2140**, resulting in a more consistent and repeatable opening of the vent **2152**. The depth, shape, and size of the groove **2140** may be easily modified simply by changing the tooling. Additionally, the vent **2152** is easy to clean and inspect since the vent **2152** (and groove **2140**) is located on an external side of the housing **2126**. For example, the groove **2140** may be inspected by a laser (e.g., to measure the size of the groove **2140**) from the outside of the cell.

[0122] Referring now to FIG. **23**, a cell housing **2226** having a vent **2252** for an electrochemical cell (e.g., cell **24**) is shown according to another exemplary embodiment. As shown in FIG. **23**, the vent **2252** is provided in a bottom portion **2230** of the housing **2226**. According to other exemplary embodiments, the vent **2252** may be provided elsewhere (e.g., such as in the lid or cover of the cell). According to another exemplary embodiment, the vent **2252** may be located in a cover or bottom that is a separate component from the housing **2226** that in turn is coupled to the housing **2226** (e.g., by a welding operation).

[0123] As shown in FIG. **23**, the vent **2252** includes a center portion **2244** that is coupled to the housing **2226** at a weakened area. For example, the vent **2252** includes at least one annular or circular fracture ring or groove **2140** (e.g., notch, cut, indentation, dimple, channel, trough, pressure point, fracture point, fracture ring, etc.) located near the outer circumference of the bottom **2230**. According to an exemplary embodiment, the fracture groove **2240** has an upside down V-shaped bottom and is configured to break away (i.e., separate) from the bottom of the housing **2226** when the vent **2252**

deploys. According to other exemplary embodiments, the bottom of the fracture groove **2240** may have another shape (e.g., rounded shape, curved shape, upside down U-shape, etc.).

[0124] According to an exemplary embodiment, the bottom of the housing **2226** may include a ridge, projection, or ring of material **2228** to prevent fracture of the vent **2252** during handling and/or assembly of the cell. The projection **2228** provides for a clearance space between the vent **2252** and a surface that the cell is set upon. According to an exemplary embodiment, the clearance space is configured to prevent the vent **2252** from being accidentally bumped (and deployed) during handling and/or assembly of the cell.

[0125] According to the exemplary embodiment shown in FIG. **23**, the vent **2252** has a slightly domed shape (e.g., similar to the bottom of a soda can). The slightly domed shape of the vent **2252** helps to add rigidity and/or strength to the vent **2252**. Further, the slightly domed shape of the vent **2252** raises the height of the center portion **2244** in relation to the bottom of the housing **2226**. In connection with the projection **2228**, the slightly domed shape of the vent **2252** aids in preventing the vent **2252** from being accidentally bumped (and deployed) during handling and/or assembly of the cell.

[0126] According to an exemplary embodiment, the vent **2252** may include features or ribs (such as, e.g., radial ribs **2290** as shown in FIG. **23**) to add rigidity and/or strength to the vent **2252**. According to an exemplary embodiment, the ribs are located on the external surface of the center portion **2244** of the vent **2252**. However, according to other exemplary embodiments, the ribs may be located elsewhere (e.g., on the inside surface of the center portion **2244** of the vent **2252**). According to another exemplary embodiment, the ribs may have a different shape and/or size (e.g., circular ribs).

[0127] According to the exemplary embodiment shown in FIG. **23**, the housing **2226** includes an internal ledge **2235** (e.g., bend, projection, ridge, etc) configured to restrict movement of a cell element (not shown) past the ledge **2235**. According to an exemplary embodiment, the cell element rests directly on the ledge **2235**. According to another exemplary embodiment, the cell element is positioned a pre-determined distance away from the top of the ledge **2235**, and moves downward toward the ledge **2235** during deployment of the vent **2252**. According to another exemplary embodiment, an insulator (e.g., a ring insulator or washer insulator **2234** as shown in FIG. **23**) may be provided between the cell element and the ledge **2235**.

[0128] According to an exemplary embodiment, a current collector (not shown) may be coupled to the vent **2252** (e.g., at laser weld **2248** shown in FIG. **23**) and to an end of the cell element. According to one exemplary embodiment, the current collector is a flexible current collector. According to this exemplary embodiment, the cell element is positioned directly on the ledge **2235** (with the insulator **2234** provided in between). During deployment of the vent **2252** (e.g., during an over pressurization of the cell), the groove **2240** fractures (due to the high pressure inside the cell) and separates from the rest of the bottom **2230** of the housing **2226**. In this embodiment, the cell element remains stationary and the current collector is allowed to move.

[0129] According to another exemplary embodiment, the current collector (not shown) is a non-flexible current collector. According to this exemplary embodiment, the cell element is positioned a pre-determined distance away from the top of the ledge **2235**. During deployment of the vent **2252**, the outer groove **2240** fractures and separates from the bottom **2230** of the housing **2226**. In this scenario, the cell element may move downward towards the vent **2252** to aid in the fracture of the groove **2240**. For example, the cell element may “push” or “punch” through the bottom **2230** of the housing **2226** (via the non-flexible current collector) to aid in deployment of the vent **2252**. However, in this embodiment, the downward travel of the cell element is limited by the ledge **2235**. Once the cell element reaches the ledge **2235** (again, with the insulator **2234** provided in between), the downward movement of the cell element is restrained.

[0130] According to an exemplary embodiment, the vent **2252** is configured to separate from the bottom **2230** of the housing when using either the flexible current collector or the non-flexible current collector. By having the vent **2252** separate from the bottom **2230** of the housing **2226**, the vent **2252** acts as a current interrupt or current disconnect device. This is because the separation of the vent **2252** from the bottom **2230** of the housing **2226** disrupts the flow of current from the cell element through the current collector and to the housing **2226**. In this way, the vent **2252** acts not only as an over-pressure safety device, but also as a current disconnect device.

[0131] According to an exemplary embodiment, the vent **2252** is formed by tooling located external the housing. The tooling tolerance is only affected by one side of the tool, allowing for a more consistent groove **2240**, resulting in a more consistent and repeatable opening of the vent **2252**. The depth, shape, and size of the groove **2240** may be easily modified simply by changing the tooling. Additionally, the vent **2252** is easy to clean and inspect since the vent **2252** (and groove **2240**) is located on an external side of the housing **2226**. For example, the groove **2240** may be inspected by a laser (e.g., to measure the size of the groove **2240**) from the outside of the cell.

[0132] As utilized herein, the terms “approximately,” “about,” “substantially,” and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numerical ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and claimed are considered to be within the scope of the invention as recited in the appended claims.

[0133] It should be noted that the term “exemplary” as used herein to describe various embodiments is intended to indicate that such embodiments are possible examples, representations, and/or illustrations of possible embodiments (and such term is not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

[0134] The terms “coupled,” “connected,” and the like as used herein mean the joining of two members directly or indirectly to one another. Such joining may be stationary (e.g., permanent) or moveable (e.g., removable or releasable). Such joining may be achieved with the two members or the two members and any additional intermediate members being integrally formed as a single unitary body with one another or with the two members or the two members and any additional intermediate members being attached to one another.

[0135] References herein to the positions of elements (e.g., "top," "bottom," "above," "below," etc.) are merely used to describe the orientation of various elements in the FIGURES. It should be noted that the orientation of various elements may differ according to other exemplary embodiments, and that such variations are intended to be encompassed by the present disclosure.

[0136] It is important to note that the construction and arrangement of the vents, electrochemical cells, and battery modules or systems as shown in the various exemplary embodiments is illustrative only. Although only a few embodiments have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter described herein. For example, elements shown as integrally formed may be constructed of multiple parts or elements, the position of elements may be reversed or otherwise varied, and the nature or number of discrete elements or positions may be altered or varied. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. Other substitutions, modifications, changes and omissions may also be made in the design, operating conditions and arrangement of the various exemplary embodiments without departing from the scope of the present invention.

What is claimed is:

1. An electrochemical cell comprising:

a housing having a first end;

a vent located at the first end that is configured to deploy from the housing to allow the expulsion of gases from within the cell; and

at least one projection extending outward from the first end adjacent the vent, wherein the at least one projection is configured to prevent accidental deployment of the vent.

2. The electrochemical cell of claim **1**, wherein the at least one projection substantially surrounds the vent and extends outward from the first end beyond an outer surface of the vent.

3. The electrochemical cell of claim **1**, wherein the vent is coupled to the first end at a weakened area.

4. The electrochemical cell of claim **3**, wherein the weakened area is a groove.

5. The electrochemical cell of claim **4**, wherein the groove comprises a first step and a second step.

6. The electrochemical cell of claim **4**, wherein the groove comprises a pointed tip.

7. The electrochemical cell of claim **4**, wherein the groove comprises a rounded tip.

8. The electrochemical cell of claim **1**, wherein the at least one projection substantially surrounds the vent and the vent includes a first angular portion located between the projection and a center portion of the vent.

9. The electrochemical cell of claim **8**, wherein the vent further comprises a second angular portion, the second angular portion located between the first angular portion and the center portion of the vent.

10. The electrochemical cell of claim **1**, wherein the first end further comprises a generally flat area located between a wall of the housing and the at least one projection, wherein the flat area is configured for mating engagement with a seal.

11. The electrochemical cell of claim **1**, wherein the vent has a thickness that is greater than the thickness of a wall of the housing.

12. The electrochemical cell of claim **11**, wherein the vent comprises a center portion having a recess.

13. The electrochemical cell of claim **1**, wherein the housing is a deep drawn housing.

14. The electrochemical cell of claim **1**, wherein the vent is a stamped vent.

15. The electrochemical cell of claim **1**, wherein the housing further comprises a second end opposite the first end having at least one terminal extending therefrom.

16. An electrochemical cell comprising:

a housing;

a vent located at a first end of the housing, the vent configured to separate from the first end of the housing to allow gases from within the cell to exit the cell; and

at least one projection extending outward from the first end of the housing and partially surrounding at least a portion of the vent, wherein the at least one projection is configured to prevent accidental deployment of the vent.

17. The electrochemical cell of claim **16**, wherein the vent is coupled to the first end of the housing by a groove.

18. The electrochemical cell of claim **17**, wherein the groove comprises a first step and a second step.

19. The electrochemical cell of claim **16**, wherein the vent includes a first angular portion located between the projection and a center portion of the vent.

20. The electrochemical cell of claim **19**, wherein the vent further comprises a second angular portion, the second angular portion located between the first angular portion and the center portion of the vent.

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